PERFORMANCE EVALUATION OF BOBE AND LAKU SMALL SCALE IRRIGATION SCHEME IN AWASH KUNTURE SUB BASIN.

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DECLARATION

I hereby declare that this thesis entitled "**Performance Evaluation of Bobe and Laku Small Scale Irrigation Scheme in Awash Kunture Sub Basin."** was composed by myself, with the guidance of my advisor, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or processional qualification. Parts of this work have been published in [state previous publication].

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APPROVAL PAGE

This thesis entitled with Performance Evaluation of Bobe and Laku small scale irrigation scheme in Awash Kunture Sub Basin has been approved by the following advisor, examiners, department head and collage dean in the partial fulfillment of Masters of Science in Hydraulic Engineering.

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ABSTRACT

This study emphasizes on comparative performance assessment of two irrigation schemes in Walmera Woreda of Awash Kunture sub-basin. The irrigation schemes based on the study area were Bobe scheme and Laku irrigation scheme within an area of 66ha and 45ha respectively. To achieve the objectives of the project primary and secondary data were collected. Those primary and secondary data collection have been carried out during field visits. From the analysis of the comparative performance indicators;-Relative water supply and Relative irrigation supply were 2.32 and 2.12 for Bobe while 1.92 and 1.75 for Laku irrigation schemes respectively. The values of WDC 1.57 for Bobe and the values of Laku was 0.3. For the outputs per unit cropped area of the value of crop production with project value of 5097.73 and 2292.31US$ birr per hectare for Bobe and Laku respectively concludes that, the income per cropped area at Bobe is better than Laku scheme. The output per command area is 6103.03 birr/ha and 3311.1for the year 2001. The output per irrigation supply is 3.2 birr/m^3 and 1.45birr/m^3 for Bobe and Laku in the year 2008 and 2009. The volume of flow per irrigated area is equal to 213408m^3 per season. The actual discharge capacity of the main canal at the system head is 150 lit/sec for Laku irrigation scheme, which was the total discharge of the two pumps .the output per unit irrigation water delivered is 2.5 birr/m^3 and 6.3m^3/ha for Bobe and Laku. The output per unit irrigation supply for Laku and Bobe is 3.3 and 2.08respectively.this implies that irrigation water Bobe is more abundant than Laku and water is used to produce at Laku. Bobe and Laku have more or less similar values, 1.2 and 0.89, respectively, implying reduction of irrigated areas by about 11% for Laku

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List Abbreviations

Ao	Cross-Sectional area.
AMD	Allowable Moisture Depletion
CWR	Crop Water Requirement
DA	Development Agent.
Du	Distribution Uniformity.
Dpi	Deep Percolation Irrigation.
EARO	Ethiopian Agricultural Research.
Ea	Application Efficiency.
Ei	Irrigation Efficiency.
Er	Requirement Efficiency.
ETc	Crop Evapotranspiration.
ET	Evapo-Transpiration.
ETo	Reference Evapotranspiration.
FAO	Food Agricultural Organization.
FMIS	Farmers Managed Irrigation System.
GPS	Global Position System
GRi	Gross Return Investment.
Ha	Hectares.
I	Irrigation

IIMI	International Irrigation Management Institute.
IK	Indigenous Knowledge.
IWMI	International Water Management Institute.
Km2	Square Kilometer.
LGP	Length of Ground Period.
Lit/sec	Liter per Second.
MoWR	Ministry of Water Resource.
OIDA	Oromia Irrigation Development Authority.
PA	Peasant Association.
Pe	Effective Precipitation.
Pmi	Participatory Irrigation Management.
Qo	Inflow Discharge.
Ric	Relative Irrigation Capacity.
Ris	Relative Irrigation Supply.
RWS	Relative Water Supply.
SSIP	Small Scale Irrigation Project.
Td	Depletion Time
Wf	Water Applied to the Field.
WDC	Water Delivery Capacity

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1. INTRODUCTION

1.1 Background

Agriculture was the core for Ethiopian economy, rainfall is becoming more erratic and unreliable from time to time as a result of global climate change and manmade climate changing factors like that of disturbance of ecosystem, environmental degradation. Most rain falls intensively, often as convective storms, with very high rainfall intensity and extreme spatial and temporal variability. These rainfall patterns affect crop and livestock production and contribute to volatility in food prices, which ultimately affects overall economic development. Irrigation influences the quality of life. One major effect is the increase in prosperity which may improve the nutrition intake and resistance of the people against disease. The problem of food security is intensified by growth of population .In fact; the prices of food stuffs in the world market have recently begun to rise. Clearly, irrigation should play an important role in raising and stabilizing demand for agricultural product, especially in developing countries. The sustainability of irrigation scheme is measured based up on its performance of fulfilling certain indicators.

Performance evaluation is major component of proper irrigation water management; the most common problem in performance evaluation of irrigation scheme is lack or non-reliability of data. In most cases people believe that irrigation scheme with modern system will have high performance, but use of modern method of field application alone doesn't guarantee high performance. Efficiency of an irrigation system depends as much or more on the capability of the irrigator as on the quality of life system, MoWR (2002).

Rapid growth of small-scale irrigation constitutes a major requirement for the agricultural development and food security strategies in the country. The planning process for the irrigated agriculture should assess the environmental management issues as well as the technical issues of irrigation performance. Small-scale irrigation for food security enhancement and sustainable environment in the rural population is technologically and socio-economically demanding option. The sustainability of small-scale irrigation largely depends on their future performance and environmental friendly conditions. With regard to the study area, Oromia is one of the largest regional states in Ethiopia with respect to population number and areal coverage.

Most part of the region is suffering from food insecurity; one third of the region is low land that is prone to drought. International water management institute (IWMI) suggests the use of minimum set of comparative indicators, which give abroad overview of the hydrological, agronomic, financial and environmental performance of irrigation systems. Since they focus on elements common to all systems (water, land and crop production) they enable to compromise the systems with different infrastructures, management types and environment, EARO (2002).

The large scale systems in the upper awash basin and elsewhere suffer from water management practices that have resulted in rising ground water table and secondary soil salinity, where large tracts of land have gone out of production (EARO, 2002). Besides management problems of large-scale irrigations, most existing modern irrigation devices do not fit the plots of smallholders, and are far too expensive (in terms of capital or running costs) to be affordable. One key, then, to increasing the agricultural productivity of small farmers is access to affordable and efficient irrigation technologies. Irrigation in the Awash basin is river-fed and poor management of irrigation systems are compounded by competition for water access by crop, livestock, small holders and large commercial farm enterprises, like sugar factories. In Ethiopia, about more percentage of the irrigation potential in terms of land and water resources has not been developed so far. However, there have been many ongoing medium and large-scale irrigation developments in recent years.

Small-scale irrigation, defined as less than 200 ha, in the peasant sector has are natively longer history in certain parts of Ethiopia. Small scale schemes are operated and managed by the water users themselves with little involvement of government agencies in some cases. Ministry of water resources (MoWR 2004) emphasizes that in Ethiopia, these schemes have been playing a significant role ensuring food security at house hold level and improving the livelihood of rural area. However, absence of continuous improvement initiatives and performance monitoring mechanisms have either challenged sustainable production or have resulted in wastage and misuse of scarce water resources in these schemes.

In addition to using process indicators (like irrigation water use efficiencies),the International Water Management Institute (IWMI) suggests using a minimum set of comparative indicators to assess hydrological, agronomic, economic, financial, and environmental performances of irrigation systems

1.2 Statement of the Problem

Dry farming systems depend on precipitation, specifically the component called green water, which is stored directly in the soil and used later as evapotranspiration. In water scarce regions, green water resources make up 85% to 90% of the precipitation, reflecting the significant proportion of the available freshwater that sustains rain fed agriculture. According to IWMI, (2007) due to lack of water storage and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one time per year and also there are frequent crop failures due to dry spells and droughts which has resulted in a chronic food shortage currently facing the country.

The intensity of recurrent droughts affects the livelihoods of the agricultural communities and the whole economy. Even in a year of good rain, the occurrence of floods affects the livelihoods of riparian residents with little capacity to neither protect from the seasonal flood nor mitigate the impact (Mc Cornick et al, 2003).As part of the development community's fascination with the field of appropriate technologies, a range of technologies, techniques and practices have been developed over the years on behalf of smallholders. However, most technologies have not been successful in their performance application, dissemination or adoption.

Development agencies have tried to encourage farmers to adopt bush pumps, rope-and-washer pumps, rower pumps, treadle pumps, pitcher pot systems, drag-hose sprinklers, hydraulic ram pumps, micro-irrigation systems, windmills, water harvesting techniques and a host of other technologies with mixed success. While it may be that some of the technologies simply did not perform up to the expectations, there is a natural tendency to over-emphasize the technology itself rather than pay attention to the process by which it is identified, modified, and disseminated.

Near the study area, Awash kunture sub basin is very much full and Bobe River is flowing through year. This calls for a need to conduct detailed to semi-detailed study on potential Irrigable land, river stream and water management system studies. The study will contribute increments of productivity of the study area through providing basic information on irrigable land, availability and quality of water and sound land management method for irrigation projects. In addition, knowledge and experience which will be gained from this study could be transferred to other similar areas of the country in order to assist the on-going irrigation projects but this needs inter networked institutional arrangements.

1.3 Objectives

1.3.1 General objective

The overall objective of the study was to evaluate the performance of small-scale irrigation by using Internal and External (comparative) performance indicators.

1.3.2 Specific objectives

To simulate the hydraulics of water delivery system to the field levels using Sirmod III Software.

To evaluate the selected small-scale irrigated schemes performance indicators (internal and comparative);

To generate baseline information and provide appropriate improvement possibilities.

1.4 Significance of the Study

This study is believed to contribute the efforts working towards attaining technically feasible and socially desirable use of irrigation water; to the initiatives striving to identify better strategies for irrigated production. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource water, if they are mismanaged. In recognition of both the benefit and hazards assessment and evaluation of irrigation schemes, performance has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that may be both effective and feasible in improving system performance.

Information on the impact of irrigation on the individual farm household in terms of food security and incremental income, equitable water use, community groups and water users associations, and environmental effects of small scale irrigation need to be well documented for planning purposes. Information collected from the study will help government policy makers, development agents, and NGOs to formulate appropriate policies, design effective evaluation and development programs.

1.4 Research questionaries'

How to manage irrigation supply systems?

How to compare the out puts of irrigation scheme based on their productivity?

How to estimate the efficiency of irrigation area?

Why Sirmod software is comprehensive for internal performance indicators?

2. LITERATURE REVIEW

2.1 Irrigation

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year. Where traditional rain-fed farming is a high-risk enterprise, irrigation can help to ensure stable agricultural production (FAO, 1997).

Three basic requirements of agricultural production are soil, seed, and water. In addition, Fertilizers, insecticides, sunshine, suitable atmospheric temperature, and human labor are also needed. Of all these, water appears to be the most important requirement of agricultural Production. The application of water to soil is essential for plant growth, so used to serve; It supplies moisture to the soil essential for the germination of seeds, and chemical and bacterial processes during plant growth. It washes out or dilutes salts in the soil; enables application of fertilizers and reduces the adverse effects of frost on crops. Etc In several parts of the world, the moisture available in the root-zone soil, either from rain or from underground waters, may not be sufficient for the requirements of the plant life.

2.1.1 Development of water resource and Irrigation in Ethiopia

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing Industrial crops in Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal Irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, Irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley (Seleshi *et al*., 2007).

Ethiopia covers a land area of 1.13 millionkm^2, of which 99.3 percent is a land area and the remaining 0.7 percent is covered with water bodies (MoWR 2002). It has an arable land area of 10.01 percent and permanent crops covered 0.65 percent while others covered 89.34 percent. It is believed that Ethiopia has a total volume of 123 billion cubic meters of surface water and about 2.6 billion cubic meters of groundwater. The distribution is not, however, uniform. The western half of the country receives sustainable amounts of precipitation and has many perennial rivers and streams while the precipitation is marginal in the eastern half of the country. The Ethiopian plateau is the source of the *Abay, Awash, Tekeze, Mereb, Baro-Akobo and Omo* rivers that flow to the west and southwest. The Baro-Akobo basin is potentially the largest possible irrigable area (about 483 thousand hectares) though only a negligible portion of it has been developed probably because of the large investment cost required and its distance from the central market, which makes it less favorable for commercial Agriculture. Awash River is the only river extensively used for commercial plantations of industrial and horticultural. Out of the total irrigated area of about 161,125 ha, over 43% is found in the Awash River basin. The remaining potential of the Awash River for irrigated agriculture is in the order of 136,220 ha (Mc Cornick et al, 2003).

2.1.2 Irrigation Categories

Irrigation development could be defined as a case of agricultural development in which technology intervenes to provide control for the soil moisture regimes in the crop root zone in order to achieve a high standard of continuous cropping. With respect to the area irrigated, scale of operation and type of control or management, irrigation is categorized either as small, medium or large scale (Seid Irrigation in Ethiopia is classified in to three classes).

Small-scale irrigation schemes are those which have less than 200 hectares of area. Medium-scale schemes cover an area of 200-3000 hectares while large-scale irrigation schemes involve those with total area of over 3000 hectares (MoWR, 2001). The development of small scale irrigation schemes for farmers and rural communities to be managed by water user associations, farmer co-operatives or water committees, is the responsibility of the regional water resources bureau and the Ministry of Agriculture and Rural development. Whilst Medium and large scale schemes to be owned and operated by private investors individually or in partnership, companies or public enterprises are the responsibility of the Federal Ministry of water resources.

2.1.3 Definition of small scale and large scale irrigation

Turner (1994) points out that irrigation system can be classified according to size, source of water, management style, degree of water control, Source of innovation, landscape niche or type of technology. Most authors, however, agree that concepts of local management and simple technology should be combined with size, and the best working definition seems to be that used by the UK Working group on Small Scale Irrigation (SSI): small scale irrigation is usually on small plots, in which farmers have the major controlling influence and using a level of technology which the farmers can effectively operate and maintain‟. There is also a case for using the term farmer-managed irrigation systems‟ (FMIS), as used by the International Irrigation Management Institute (IIMI), which removes the confusion with authority-managed small-scale irrigation.

In general, an important characteristic of FMIS is that the farmers also control and manage the water abstraction from its source. Governments often classify these systems as “small- scale irrigation system” or “minor irrigation systems,” although examples of FMIS may be found with command areas of hectares. FMIS are also known as traditional, indigenous, communal or people’s systems.

2.1.4 Regulation of water discharge and water levels

The Measurement of irrigation water is an essential element for its fair distribution and economical use. Irrigation scheme flows are controlled with the help of hydraulic structures and water reaches at the fields at the proper time and in its quantities needed. To transport water from the source to the fields, an infrastructure consisting of canals and a regulation structure is necessary. The water level and velocity control structures comprise a group of engineering works installed in open canal irrigation networks designed to regulate the water level in a canal, to control the quantity of water passing through it, to dissipate energy and enable water to be delivered accurately and safely to the fields without causing erosion. Such structures include checks or cross-regulators, drops (or falls) and chutes. Water controls refers to the ability of the system to distribute, apply or remove water at the right time, quantity and place.(Solomon, K H, 1998).

The main objectives of water control in an irrigation project are to deliver reliability (temporal), adequacy (volume balance, including seepage, operational and application losses) and equitable water to irrigation fields (parameters). The collection, control, allocation and distribution of water to groups of fields and producers are the core processes of an irrigation system. Irrigation systems collect; transport and distribute water for agricultural production with the goal to supply the root zones of the cultivated crops with the necessary amount of water.

2.1.5 Participatory irrigation management (PIM)

Any irrigation project cannot be successful unless it is linked to the stakeholders, that is, the farmers themselves. In fact, people's participation in renovation and maintenance of field channels was the established practice during the pre-independence days. However, the bureaucracy encroached on this function in the post-independence period and a realization has dawned that without the participation of farmers, the full potential of an irrigation scheme may not be realized. Though a water resources engineer is not directly involved in such a scheme, it is nevertheless wise to appreciate the motive behind PIM and keep that in mind while designing an irrigation system.

The national water policy stresses the participatory approach in water resources management. It has been recognized that participation of the beneficiaries would help greatly for the optimal upkeep of irrigation system and utilization of irrigation water. The participation of farmers in the management of irrigation would give responsibility for operation and maintenance and collection of water rates from the areas under the jurisdiction of the water user's association of concerned hydraulic level (Burt, C M and Styles, S W, 2000).

The sustainability and success of PIM depends on mutual accountability between the water user's association and the irrigation department of the concerned state, attitudinal change in the bureaucracy, autonomy for the water user's associations, multifunctional nature of the water user's association and the choice of appropriate model for PIM with appropriate legal and institutional framework. If the farmers have to take over and manage the system, then the system must be rectified by the irrigation department to a minimum standard to carry the design discharge before it is handed over to the water user's association. The success of the PIM is also linked to the introduction of rotational water supply and water charges with rationalized establishment costs.(Burt M,1995).

2.1. 6 Management of water for irrigation

Management of water is mostly the purview of the water resources engineer; Amount of water available at a point of a surface water source, like a river (based on hydrological studies).Availability of ground water for utilization in irrigation system without adversely lowering the ground water table. An excess of water for an irrigated agricultural fields which may cause water logging of the fields. In order to find proper solution to these and other related issues, the water resources engineer should be aware of a number of components essential for proper management of water in an irrigation system.

Watershed development: since the water flowing into a river is from a watershed, it is essential that the movement of water over ground has to be delayed.

Measures for the water shed development also includes a forestation within the catchment area which is helpful in preventing the valuable top-soil from getting eroded and thus is helpful also in preventing siltation of reservoirs.

Water management: surface water reservoirs are common in irrigation systems and these are designed and operated to cater to crop water requirement throughout the year. It is essential, therefore, to check loss of water in reservoir due to; Evaporation from the water surface, seepage from the base and reduction of storage capacity due to sedimentation.

On farm water management: Though this work essentially is tackled by agricultural Engineers, the water resources engineers must also be aware of the problem so that a proper integrated management strategy for conveyance-delivery-distribution of Irrigation water is achieved. It has been observed from field that the water delivered from the canal system to the agricultural fields are utilized better in the head reaches and by the time it reaches the tail end, its quantity reduces.

2.1.7 Farmer Managed Irrigation System (FMIS) changing trends

According to Jorge (1993), irrigation system falls in two broad categories: those in which the Principal management responsibility is exercised by government agencies with the farmers playing a subsidiary role, and the most management activities are carried out and decision made by the farmers themselves with the government providing periodic technical or logistical support. The latter category in which farmers assume the dominant role is referred to as Farmer-Managed Irrigation Systems (FMIS). In Ethiopia, irrigation schemes are classified into small, medium and large scale. Small-scale schemes are those covering an irrigated area of less than 200 hectares and growing primarily subsistence crops (McCormick *et al*, 2003).

These schemes were often seen as an ideal way to increase food production and reduce dependence on the variability of rainfall. They were also prestige developments, and later similar schemes appealed particularly to newly independent countries and attracted to large amounts of foreign aid, especially in the 1960s and 1970s (Jorma,1999).Turner (1994) also described other reasons for the appeal of such schemes to governments and to donors.

However, many problems became apparent when these large- scale schemes failed to live up to the expectations, costing far more and producing much lower crop yields than estimated and introducing many new problems while alienating the majority of farmers. In recent years, there has been an emphasis on the concept of sustainable development, which is often incompatible with increasing river regulation.

2.1.8 Purposes and need for small-scale irrigation in Ethiopia

Faced with a poverty driven depleted resource base, the risk averting strategy that has been followed by the rural community is increasing unsustainable pressure on natural resources leading to land and water depletion and degradation and/or forced" migrations to urban areas. This situation will remain a challenge until a high rate of agricultural transformation coupled with maximum and sustainable agricultural productivity (per unit area of land-intensification) takes off from the present crisis. Realizing the present socio-economic situations, it is evident that Ethiopia cannot meet its food security and food self-sufficiency objectives using the prevailing land and water use systems (Mc Cornick et al, 2003).

Small-scale irrigation has been chosen by the majority of the cooperating sponsors as a strategic intervention to address food security in Ethiopia). A number of factors led to this choice. The most obvious of which is that irrigation increases the potential for producing more food more consistently in the drought-prone food-insecure areas. This remains the central theme for these activities and investments. Another factor favoring the adoption of irrigation was that irrigation was seen as a “window of opportunity” to avert the food shortage during the mid-1980s, despite decades of traditional efforts at promoting small scale irrigation scheme. Getting good statistics on small-scale irrigation, which also includes traditional schemes, is understandably difficult.

At present, the figures most frequently cited estimate a total of approximately 65,000 hectares in Ethiopia. These same documents, however, raise the issue of the need for rehabilitation and upgrading many of these schemes. These figures are in sharp contrast to the widely cited overall potential for irrigation throughout the country, including small, medium and large- scale irrigation, which is thought to be possible in the ranges of 1.8 to 3.4 million hectares, of which anywhere from 180,000 to 400,000 hectares are considered potentially developable as small-scale themes (Tom et al, 1999). This kind of data and information is particularly important for understanding sector development options and policy. It can be a real constraint if the data is un-clear, extremely varied and considered unreliable.

2.1.9 Traditional small-scale irrigation innovations

In Ethiopia, irrigation schemes are classified into small, medium and large scale. Small-scale schemes are those covering an irrigated area of less than 200 hectares and growing primarily subsistence crops. Small irrigation schemes serve mainly to supplement rainfall and provide a greater degree of security to peasant farmers (Mc Cornick et al, 2003).

Because of increasing trend of population growth in the last six decades, (from 17 million in 1940 to 63 million in 2000) and increased exploitation of land resources, the balance of water resources has also been negatively affected. Although traditional small scale irrigation practices existed in a few places, scaling-up activities must have started since the 1960s. The traditional irrigation practices by the Farmers have some setbacks like: High labor requirement to build canals, Gully formation as a result of deep canals and lack of water control to each canal resulting in poor water distribution to the stakeholders. However, farmers growing some high value cash crops and living near market centers use small pumps and generators to raise water to higher points for gravity application. Out of necessity, farmers adopt the principle of irrigation from their relatives and neighbors. Some farmers have adopted irrigation practice provided water is available. Jorma (1999) discussed further on the problems faced by the SSI in Ethiopia and lists some of them as follows:

1. In a number of instances, SSI development was almost exclusively focused on the operations associated with constructing the head works and primary canal.

Schemes are not designed with feasible command areas that justify the capital costs of the major head works and primary canal.

2. SSI schemes operating on the basis of uncertain data regarding water supply will be more severely affected by any losses to net water availabilities, including leakage within the system, evaporation from surface waters (of particular concern with reservoirs) and a poor grasp of proper irrigation water management by the Development Agents (DA) and the farmers.

2.2 Performance evaluation of small-scale irrigation

The principal objective of evaluating surface irrigation systems is to identify management practices and systems that can be effectively implemented to improve the irrigation efficiency. Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control.The performance of any irrigation system is the degree to which it achieves desired objectives. As many FMIS do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement (Jorge, 1993).

The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters. To identify problems in its function, and to develop alternative means for improving the system (FAO, 1989). Public agencies in many developing countries want to assist farmer- managed irrigation systems improve their performance through better management. And, better management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives (Oad & Sampath, 1995).

Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions. The development potential for small- scale irrigation seems attractive in view of cost effectiveness, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and setbacks that hinder the introduction of small- scale irrigation. Regarding the different approaches of soliciting evaluation data, it can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year. The other means of collecting the evaluation data is through conducting assessment research. The types of performance measures (indicators) to be chosen depend on the purpose of the performance assessment activity (Molden *et al*., 1998). With these indicators, the amount of deviation between the actual values against the intended are evaluated.

2.2.1 Performance gaps existing in irrigation management

Performance is assessed for a variety of reasons: to improve system operation and to assess progress against strategic goals. as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity (Molden et al, 2008).There are four potential kinds of performance gaps that can occur with irrigation systems (Douglas and Juan, 2009). The first is a technological performance gap. This is when the infrastructure of an irrigation system lacks the capacity to deliver a given hydraulic

Performance standard. The normal solution to technology performance gaps is to change the type, design or condition of physical infrastructure.

The second kind of performance gap is when a difference arises between how management procedures are supposed to be implemented and how they are actually implemented. This includes such problems as how people adjust gates, maintain canals and report information. This can be called a gap in implementation performance. A problem of this kind generally requires changes in procedures, supervision or training.

The third kind of performance gap is a difference between management targets and actual achievements. Examples of management targets are the size of area served by irrigation in a given season, cropping intensity, irrigation efficiency, water delivery schedules and water fee collection rates. This can be called a gap in achievement. Such problems are generally addressed either by changing the objectives (especially simplifying them) or increasing the capacity of management to achieve them - such as through increasing the resources available or reforming organizations.

The fourth type of performance problem concerns impacts of management. This is a difference between what people think should be the ultimate effects of irrigation and what actually results. These are gaps in impact performance and include such measures as agricultural and economic profitability of irrigated agriculture, productivity per unit of water, poverty alleviation and environmental problems such as water logging and salinity.

2.2.2 Indicators of irrigation performances

It is useful to consider an irrigation system in the context of nested systems to describe different types and uses of performance indicators (Small and Svendsen, 2011). An irrigation system is nested within an irrigated agricultural system, which in turn can be considered part of an agricultural economic system. For each of the systems, process, output, and impact measures can be considered. Process measures refer to the processes internal to the system that lead to the ultimate output, whereas output measures describe the quality and quantity of the outputs where they become available to the next higher system (Molden et al, 2009).

An irrigation system, consisting of a water delivery and a water use subsystems, can be conceptualized to have two sets of objectives. One set relates to the outputs from its irrigated area, and the second set relates to the performance characteristics of its water delivery system (Oad and Sampath, 2005).

Bos (2007) summarizes the performance indicators currently used in the Research Program on Irrigation Performance (RPIP). Within this program field data are measured and collected to quantify and test about 40 multidisciplinary performance indicators. These indicators cover water delivery, water use efficiency, maintenance and sustainability of irrigation, environmental aspects, socio-economic and management. He also noted that it is not recommended to use all described indicators under all circumstances.

The number of indicators you should use depends on the level of detail with which one needs to quantify (e.g, research, management, information to the public) performance and on the number of disciplines with which one needs to look at irrigation and drainage (water balance, economics, environment, management).indicators of the irrigation performance can be categorized in two; comparative (external) indicators and internal (process) indicators.

2.2.3 Properties of performance indicators

A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It further should contain information that allows the manager to determine if the deviation is acceptable. Some of the desirable attributes of performance indicators suggested by Bos (1997) are:

The indicators must be quantifiable*:* the data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible.

Reference to a target value*:* this is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values and their margin of deviation should be related to the level of technology and management (Bos et al, 1991).

Provide information without bias*:* ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments.

Ease of use and cost effectiveness*:* particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources.

2.2.4 Purposes of performance indicators

IWMI's minimum set of external indicators was originally presented by Perry (2006). The indicators have been widely field-tested and slightly amended. The intent of presenting this set of indicators is to allow for cross-system performance. Some of the features of the indicators are the following (Molden *et al*., 1998). The first indicators relate to phenomena that are common to irrigation and irrigated agricultural systems. These set of indicators were small, yet reveals sufficient information about the output of the system. Their data collection procedures are not too complicated or expensive. The indicators also relate to outputs and are bulk measures of irrigation and irrigated agricultural systems, and thus provide limited information about internal processes.

2.3 Comparative performance indicators

External performance indicators, evaluate irrigation systems based on relative comparison of absolute values, rather than being referenced to standards or target. External indicators are used to relate outputs from a system derived from the inputs into that system. They provide little or no detail on internal processes that lead to the output. For example, the critical output of an irrigation system is the supply of water to crops. This output in turn is an input to a broader irrigated agricultural system where water combined with other inputs, leads to agricultural production.

Common indicators defined in the literature include: Conveyance, distribution, field and application, and project efficiencies, reliability and dependability of water distribution, equity or spatial uniformity of water distribution and adequacy and timeliness of irrigation delivery Irrigation efficiencies can be measured in many ways and also varies in time and management. Very "efficient" system by some definitions can be very poor performers by other definition. Lesley (2002) supplemented this idea and explained it as the public's perception of irrigation efficiency is focused mostly on water use, whereas farmers perception relates more to production. For this reason, it is unrealistic to use one all-encompassing definition. For instance, where water is very short, efficiency may be measured as crop yield per cubic meter of water used, or profit per millimeter of irrigation.

2.3.1. Irrigated agriculture performance indicators

It expresses output of irrigated area in terms of gross or net value of production measured at

Local or world prices. This addresses the direct impact of operational inputs in terms of such Aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility.

2.3.2 Water use performance indicators

This deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity.

2.3.3 Physical performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Among those reason water scarcity and input availability are the main reason why lands in command area are not fully under irrigation in a particular season. From physical performance irrigation ratio and water delivery ratio are the two main indicators.

2.3.4 Economic performance indicators

This indicator considers the production and the total cost of infrastructure for each scheme. It Deals with the total revenues from the scheme, total cost spent for running the project and initial Investment costs.

2.4 Internal performance indicators

These indicators examine the technical or field performance of a project by measuring how close an irrigation event is to an ideal one. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal how irrigation is applied to the field.

2.4.1 Conveyance efficiency

Significant volume of water is lost by the networks of the conveyance canals due to seepage and Evaporation depending on the nature of the soil and agro-climatic zone in which the canals are Located. Conveyance efficiency is defined as the ratio of the amount of water that reaches the Field to the total amount of water diverted into the irrigation system. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined. The amount lost depends on quality of operation, and maintenance, and the nature of the soil that affects the seepage rate.

2.4.2 Application efficiency

Depending on the type of the source, water is diverted, or pumped to a canal or pipe for Conveyance to the farm for distribution and finally for application to the crops in the field. When Water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and as Runoff.

The efficiency terms determine these components and compare them with the volume of Water actually applied to the field is regarded as application efficiency. The Application Efficiency is a term initially formulated by Israel son (1950) and measures the ratio between the volumes (depth) of water stored in the root zone for use by the plant to the volume (depth) of water applied to the field.

2.4.3 Deep percolation ratio

A component of the irrigation applied to a field percolates into the soil below the root zone. Part Of the water is intentionally added to the irrigation water to maintain the salt balance of the soil through leaching additional salt brought by the irrigation water itself or through capillary process

2.4.4 Storage efficiency

Storage efficiency is an index used to measure irrigation adequacy. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root Zone. The value of Er is important either when the irrigations tend to leave major portions of the Field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs. This parameter is the most directly related to the crop yield since it will reflect the degree of Soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good Practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level (Walker, 1989). Adequacy has significant impact on the crop yields and thus on the economic return on water use.

2.4.5 Distribution uniformity

Distribution uniformity is closely related with the advance ratio (AR), the ratio between the advance time and the time of irrigation. Large advance ratio and low distribution uniformity indicate too long a furrow or too small initial stream. It also indicates too small management allowed deficiency (MAD), or too large furrow spacing (Jensen, 2008).

Infiltration, which is the movement of water into the soil, is an important factor affecting surface irrigation in that it determines the time the soil should be in contact with water (the intake opportunity time or the contact time). It also determines the rate at which water has to be applied to the fields, thereby controlling the advance rate of the overland flow and avoiding excessive deep percolation or excessive runoff.

3. METHODOLOGY

To demonstrate the potential use of irrigation performance indicators evaluation of irrigation system, two small schemes from upper awash basin will be considered. These two irrigation projects may base on the information to be collect from oromia irrigation development authority (OIDA). Generally, the methodology by which study is going to take can be identified in to the study design, data collection methods.

3.1 Description of the Study Area.

The Awash River basin starts from the Ginchi watershed in the central highlands of Ethiopia and flows towards Djibouti with the total length of 1200km.The basin covers a total area of 110,000 km2 of which 64,000km2 comprising its western catchments, drains to the main river of its tributaries.

The river awash emanates at an elevation of about 3000m in the central Ethiopian highlands. The awash basin has been the most insensitively studied river basin in Ethiopia and because of its strategic location, good access facilities, available land and water resources, is currently the most developed river of Ethiopia in terms of its irrigated agriculture.

A number of tributary rivers draining the highlands east wards can increase the water level of awash river in a short period of time, especially during August and September and causes flooding in the low lying alluvial plains along the river course.Tributeries to awash river such as *Kessem, Kebena, Hawadi, Atayejara, Mille and Logiya* rivers contributed most to the lowland flooding in Afar (Mc cornick, 2003).

The irrigation potential for the Awash basin is estimated to be 206,000 ha. But so far only 42.7% (88,000 ha) have been developed. Out of these, 26.5 %(23,306 ha) are under traditional and modern small-scale irrigation. The remaining 73.5 % (64.694 ha) are developed under state farms and private investors. These include several agro-industries such as sugar factories and horticultural farms, ranches and cattle fattening, resort areas and other small industries (McCornick, 2003).

Based on its physical and climatological characteristics, the basin is divided into the following four zones: the upper basin, the upper valley, the middle valley and the lower valley (Tena, 2002).The upper valley of the Awash River basin, where the study area is located, is the area between the Koka dam and Awash station in which the river traverses some 300 km. The altitude ranges from 1000-2000 m.asl; and annual rainfall varies from 600-800 mm. The dominant agriculture is grazing and irrigated cash crops.

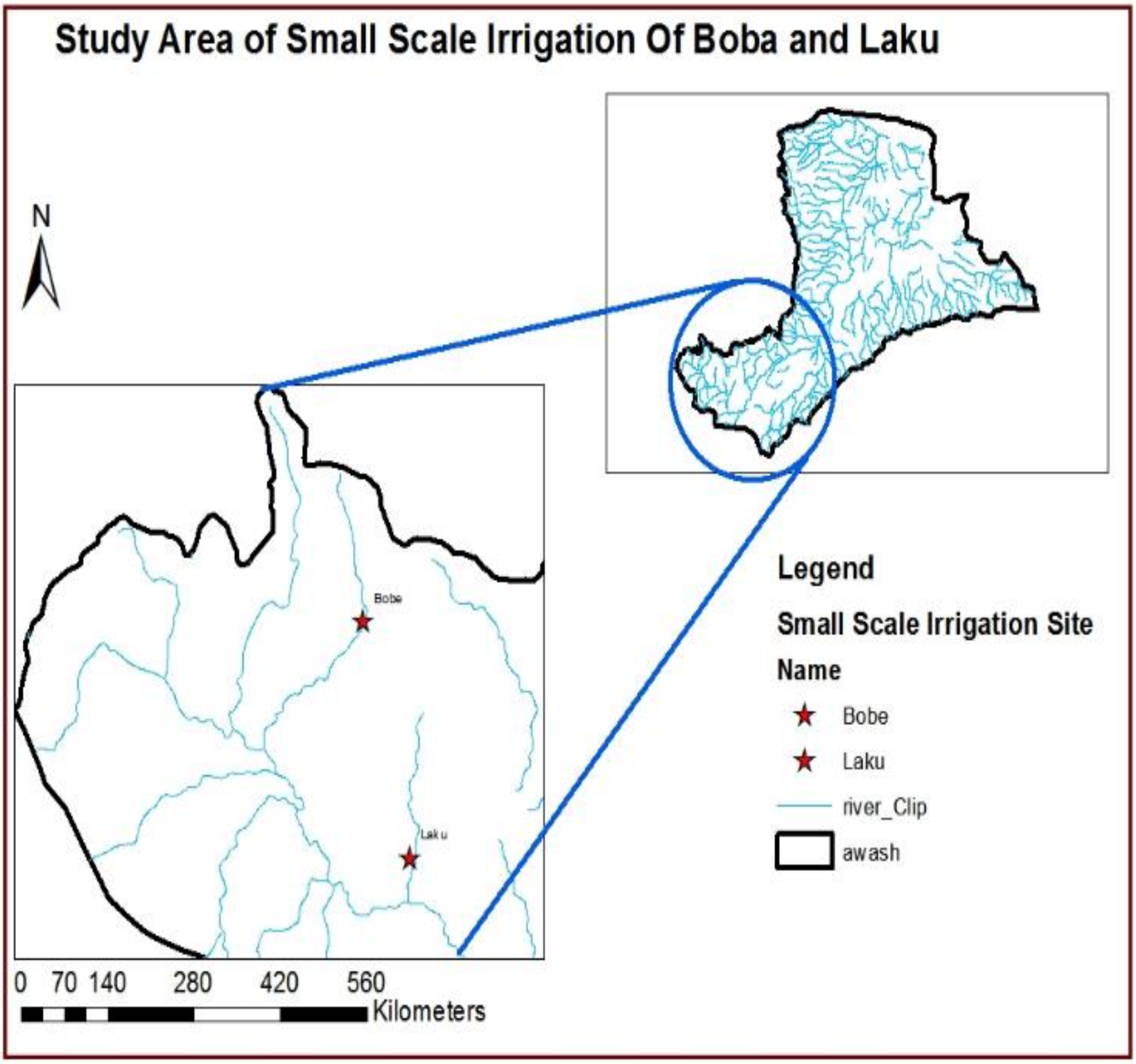

Figure 1: Map of A wash Basin and study area

3.1.1 Bobe small scale irrigation scheme

The Bobe SSI project is found in Oromia Regional state, Special zone of oromia, Welmera District and Barfata kebele, which is 8.5km from Holota town. The weir site GPS reading is 452177.1537east and 995566.6649 north and 2429.74 elevations. The river finally drains to Holota River sub basin and thus it is in awash basin. The Agro-climatic zone of the project area is classified in lower kola zone having the length of growing periods (LGP) 150-180 days .The mean temperature fluctuate between 14.7 – 17.4^{0}C .

The irrigation management system in Bobe irrigation scheme was carried out into four groups. There was irregular irrigation interval in the scheme which varied from five to seven days; depend on their cycles .the water distribution system is rotational type regarding to the scheduling of those groups turn by turn. The irrigation intervals period of the crops commonly grown in the area is about four to five days; these may increases five to six days at the end of growing season.

A representative farmer assigned by the association throughout the year manipulates the gate at diversion weir. Once it is opened, it stays till the rain season comes with regular two over- night interruptions for canal cleanings. The representative farmer makes water allocation between Berfata 1 and2 (bobe) and it is basically governed by the discharge of the Bobe River. The distribution can be allocated day and night rotation or for specific period (days interval) within a week. As far as the schedule of irrigation water allocation is for the PA he belongs, farmers have the right to apply the water as much as he wants. That means there is no any restriction how much water a farmer can divert for his field regardless of the size of his farm, especially for head end users. From field observation and results of the questionnaire, due to unwise use of water by the head end users and siltation problems of the main canal the tail end user faced water shortages frequently Accordingly the physical characteristics of the soil conducted .Since our project is small scale irrigation project (SSIP) the study is not supported by conducted soil chemical property.

Methodologies used for the study; General Field visit and observation had been taken to know the variation of texture, structure, effective soil depth etc. the result of field studies showed the entire command area was found to be similar in texture, effective soil depth and topographic features. Transact walk was used and test by using feeling methods. According to our visual investigation the following physical properties was observed.

Soil texture and structure***;*** Soil texture influences soil qualities such as infiltration rate, moisture and nutrient retention, drainage, tilts and susceptibilities to erosion. The properties of the top soil surface layer determine the ease or difficulty of cultivating land. According to our observation the textural classes of the project of area is dominated by Clay loam. The soil structure of project has good workability, good drainage characteristics, not sensitive to erosion and has no any limitation for irrigation development.

Soil depth**;** Effective soil depth is the depth of the soil at which normal crop roots growth is limited and affected by the presence hardpan, toxic, compacted layers, rocks or gravel layer and high water table. The project area has medium to deep depth at the head of the command area and deeper from middle of the command to the tail.

Diversion head work structures

Structures which are constructed across a river to divert towards the off taking canal. From various purposes of diversion head works; regulate the supply of water into the canal, control the entry of silt into the canal, to raise water level in the river and store water for short period of time. From types of diversion head work structures, Bobe small scale irrigation project uses over flow weir structures.

Weir; the major part of the entire ponding of water is achieved by the shutter or without shutter in case of Bobe project. These means crest level is equal to pond level. A type of weir is Broad crested masonry weir. The Length or span of the weir overflow was taken **9m** from the existing situation of the river section.

Figure 2: Diversion Weir structures of Bobe scheme

Table 1: Proposed of cropping pattern of Bobe irrigation scheme

NO	Crop type	Planting /sowing month			Length of growing season
		(%)	Starting Month	Finishing month	
1	Potato	40	Mid –Nov.	Mid-Dec.	120 days
2	Garlic	20	Early-Nov.	Early-Dec.	150 days
3	Cabbage	10	Early-Feb.	Mid-Feb.	120 days
4	Beetroot	10	Mid-Jan.	Late-Jan.	100 days
5	Onion	20	Early-Jan.	Early-Feb.	120 days
@	**TOTAL**	**100**			

Table 2: Proposed cropping pattern Laku irrigation scheme

NO	Crop type	Planting /sowing month			Length of growing season
		(%)	Starting month	Finishing month	
1	Onion	30	Mid -July	Early -July	Late- October
2	Potato	20	Early- June	Mid -June	Late- October
3	Garlic	20	Early -June	Mid -June	Late- October
4	Bean/peas	10	Early -June	Mid -June	Late- October
5	Maize	10	Mid -April	Late -April	Mid –October
6	Potato	10	Mid - April	Late- April	Mid – July

Figure 3: Main canals off take structures of Bobe scheme

3.1.2 Laku small scale irrigation scheme

Laku Small Scale Irrigation located at a distance of 6.5 km from Holota town and about 5.5 from Bobe SSI. It is also located in Godicha Kebele of welmera woreda District, oromia special zone at a distance of 42 km from Addis Ababa. Geographically, the scheme is located at27^{0} $50^{;}$ north latitude and 38^{0} $42^{''}$ east longitude at an elevation of 1446 meters above sea level. The scheme comprises an area of 42 ha and 93 beneficiary households. Prior to the development of the Laku Irrigation project, the life of the farmers in the vicinity were relied on the production of rain fed crops and livestock. The agricultural production was not satisfactory due to the fact that the rainfall is low for diversified crop growth.

Figure 4: Diversion pump of Laku irrigation scheme

3.2 Collections of data

For the study all the necessary data is going to collect from oromia irrigation development authority or from zonal irrigation office and from oromia water works design and supervision enterprise .Moreover, some discussions also made with farmers and the development agencies of the area to cross check the secondary data obtained. Data collected includes: production, price of crops, area irrigated, cropping pattern, amount of water harvested and climatic data.

3.2.1 Primary data collection

Frequent field observations were made to observe and investigate the method of water applications, and practices related to water management techniques made by the farmers.

Measurements of water discharge at diversion (pump) points of each irrigation scheme were Taken and also at the initial and final points of secondary, tertiary and field canals. To determine Soil texture of each farmer's field, nine soil samples from three locations from each scheme at three different depths was collected. And also using core sampler undisturbed soil samples were collected from different depths and the bulk densities at different depths were determined.

Primary data collection includes; frequently field observation makes to the assessments of water applications and practices water management systems by the farmers. Measurements of water discharge at diversion points of each irrigation schemes and to determine soil textures of each farmers field.

3.2.2 Flow measurement

For the purpose of flow measurement parshall flumes of the standard size 3 inches were made for workshop of Holota Research Center and calibrated on field before data collection. To determine the amount of water applied by the irrigators to the field, during an irrigation event, three inches (3‟) Parshall flumes were installed at the entrance of test plot. Frequent readings were taken when the farmers irrigate the test plot. Irrigation was continuing until the farmers‟ thought that enough amount of water is applied to the field. When the irrigator completed irrigating the test plot, the average depth of irrigation water passing through the flume and the respective time were recorded for the sizes of test plot being irrigated. The discharge was computed using equation (3.1) and the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer‟s decide that enough water has been applied to their fields. (Walker and Skoerboe, 1987):

$$QF=Cf x W x hu^{nf} \quad \text{......} 3.1$$

Where *Qf* is discharge for free flow condition; *W* is throat width*; hu* is upstream heads of parshall flume; *Cf* is free flow coefficient; *nf* is exponents for free condition and *H* is upstream heads of parshall flume (m). The values of W, *Cf* and *nf* are presented in Appendix and the depth of water applied was computed from discharge, cut-off time and area irrigated. The time of cut-off was the time farmer's decide that enough water would have been applied to their fields.

3.2.3 Conveyance efficiency determination

Current meter; the current meter is a widely used mechanical device for the measurement of flow velocity and, hence, the discharge in an open channel flows. It consists of a small wheel with cups at the periphery or propeller blades rotated by the force of the flowing water, and a tail or fins to keep the instrument aligned in the direction of flow. The cup-type current meter has a vertical axis, and is a more rugged instrument which can be handled by relatively unskilled technicians. The propeller-type current meter has been used for relatively higher velocities (up to 6 to 9 m/s as against 3 to 5 m/s for the cup-type current meter). The small size of the propeller-type current meter is advantageous when the measurements have to be taken close to the wall. The propeller-type meter is less likely to be affected by floating weeds and debris, (G.L. ASAWA, 2005).

3.2.4 Secondary data

For each of the selected irrigation schemes, secondary data were collected from the Oromia irrigation development authority and Holota research center. Furthermore walmera wereda sectors were visited periodically to gather further information like feasibility study documents, production costs, investment cost and other relevant information. The secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season, production cost per season, incomes generated by the irrigation associations and cropping pattern. Climatic data of the irrigation schemes were collected from the nearby metrological station. Holota Research Center was the source of the climatic data for both Bobe and Laku irrigation scheme.

3.4 Data analysis

The collected data has been summarized for analysis and for the performance indicators, data analysis such as statistical tools was implemented for evaluating this performances.

3.4.1 External performance indicators

The comparative performance indicators rely on the secondary data .The minimum sets of comparative performance indicators applied for the present study were developed by IWMI. Relative water supply and relative irrigation supply are used as the basic water supply indicators.

The types of data recorded by each irrigation projects have different natures and limited the application of all the nine parameters used in the comparative performance indicators developed by IWMI for the same cropping season of the two irrigation projects. Based on the minimum set of comparative performance indicators; evaluation of each project for individual performance, the comparison of the two irrigation project were studied as follows.

3.4.1.1Evaluation of the individual irrigation projects

The minimum set of comparative performance studies are; Relative irrigation supply (RIS), Relative irrigation capacity (RIC), Water delivery capacity (WDC), and Gross return on the investment (GRI) .from the above lists of evaluations, the relative water supply (RWS) & relative irrigation supply (R I S) are the common.

RWS=TWS/IR……………………………………………………………………....3.2

RIS=IS/ID………………………………………………………………………...3.3

WDC (%) =$Canal\ capacity/peak\ consumptive$………………………………………….3.4

GRI (%)=$Production/return\ investment$……………………………………….......3.5

Where production is output of irrigation project and Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the production. Both RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched whereas WDC is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands.

Output per cropped area (birr/ha) =$production/irrigated\ crop\ area$…………………….3.6

Where; Irrigated crop area (ha) is the portion of the actually irrigated land (ha) in any given irrigation `season, Command area (ha) is the potential scheme command area. Finally the economic indicators deal with how much investment cost is spent on the project in comparison with total production and yearly maintenance and operation expenditure and whether system is self-sufficient or not.

The economic performance indicators used in the evaluation for this particular study were gross returns on investment and financial self-sufficiency. The gross return on investment was calculated as the ratio of production to the cost of infrastructure at the Irrigation scheme and the financial self-sufficiency was calculated as the ratio of revenue from irrigation to the total operational and maintenance expenditure (Vermillion, 2000).

Output per unit command (birr/ha) = ${}^{production}/_{command\ area}$…………………..... 3.7

Output per unit irrigation supply (birr/m^3) =$production/irrigation\ supply$……………3.8

Output per unit water consumed (birr/m^3) =$production/volume\ of\ water\ consumed$.3.9

Financial efficiency= $revenue\ from\ irrigation/Total\ operation\ \&\ mentenance$…. 3.10

3.4.2 Irrigated Crop Production

Farmers in Bobe Kebele practices traditional irrigation production and Bobe River is the major source of water for irrigation. Bobe River is only source of water both for humans and livestock population. Some of the important crops grown under traditional irrigation system are Potato, carrot, Cabbage, maize, and Beet root and tomato.

Table 3: Existing Cropping Pattern initially Irrigation area for Bobe

No	Major Crops	Area (ha)	Area (%)	A/ yield /ha (Qt)	Remarks
1.	Potato	18.0	27.27	200	Local seeds without fertilizer
2.	cabbage	6.0	9..09	115	Local seeds without fertilizer
3.	tomato	1.25	1.89	---	Local seeds without fertilizer
4.	maize	17.0	25.75	170	Local seeds without fertilizer
5.	Beet root	4.8	7.2	175	Local seeds without fertilizer
6	Carrot	19.0	28.78	224	Local seeds without fertilizer
Total		**66.00**	**100.00**	**-----**	

Table 4: Existing crop pattern initially irrigation area for Laku

No	Major Crops	Area (ha)	Area (%)	A/ yield /ha (Qt)	Remarks
1.	Potato	18.0	40	200	Local seeds without fertilizer
2.	onion	6.0	13.3	115	Local seeds without fertilizer
3.	Tomato	14	31.1	---	Local seeds without fertilizer
4.	Maize	7.0	15.6	170	Local seeds without fertilizer

3.5 Determination of field application efficiency

After the water is conveyed through canal system to the off take, the water is distributed to the farmers' field inlet. The ultimate goal is to apply it as uniformly as possible over the field, at an application depth which matches the water depletion of the root zone.

Application efficiency has been common measure of relative irrigation losses and this definition is valid for all situations and all irrigation methods. Losses from the field occur as deep percolation and as field tail water or runoff and reduce the application efficiency. To compute E $a$it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, i.e. the amount of under irrigation in the soil profile must be determined as well as the losses (FAO,2009).
Application efficiency does not allow the Engineer to segregate deep percolation losses from tail water losses and it is difficult to assess the degree of under irrigation.

Application efficiency=$(water\ added\ to\ root\ zone/water\ added\ to\ field) * 100$…...3.11

3.5.1 Effect of depth of application on efficiency.

The purpose of an irrigation turn is to provide water can be stored within the root zone of the crop so that the plants can draw on this water during the period between successive irrigations.

In accordance with good irrigation practice, the depth of water applied per irrigation is mainly a function of root depth and the moisture storage capacity of the soil. If less water is applied, the technical limitations of surface application methods are such that no uniform water distribution can be achieved, resulting in allow field application efficiency.

There are two additional restrictions that should be noted for surface irrigation; in general and blocked-end borders as well. Those are depth lower than 0.1m; this is for stable soils in which flow velocity is from 12-15m/min another is depth greater than 0.2m in heavy textured soils in which flow velocity is from 10-12m/min for unstable soils that results excessive field erosion.

The application efficiency should be maximized subject to the limitation on erosive velocity, the availability and total discharge of the water supply and farming practices .the inflow should be reduced and the procedure repeated until a maximum Ea is determined.

3.5.2 Determination Distribution efficiency

After the irrigation water has been conveyed to the farm or group inlet through the main lateral and sometimes sub-lateral canals the subsequent stage is their distributions to the various fields .to obtain a reasonable efficiency network should be well designed and be operated by skilled farmers or a common irrigator representing a group of small farmers.

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a water front will advance at monotonically decreasing rate until it reaches the end of the field (FAO, 1989). It has also been explained that water lost to percolation below the root zone due to non-uniform application or over-application water runoff from the field all reduces irrigation efficiencies. To get a complete picture of an irrigation performance you need to know more indicators than just discussed above, because these are averages taken over the entire length of the field or furrows.

(DU= minimum infiltration depth / Average infiltration depth)

To determine the distribution uniformity of irrigation water in these furrow layouts auguring were done at selected points, starting from the initial to the end of the furrows at regular interval. And at each selected points of the furrow soil samples were collected at different depths with an interval of 30 cm up to 90 cm. And the soil moisture contents of the soils at the selected points were analyzed to determine the depth of water penetration. For calculating the distribution uniformity the root depth of the crop was taken as the zone of distribution and the absolute distribution uniformity equation:-

3.5.3 Determination storage **efficiency**

The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation. The water requirement efficiency, Er, which is also commonly referred to as the storage efficiency is defined as (FAO, 1989).

Er = Volume of water added to the root zone storage/Potential soil moisture storage volume

Small irrigation may lead to high application efficiency the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. Water stored in the root zone is not 100% effective.

3.6 Irrigation Scheduling

The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation. Hence the importance of irrigation scheduling is that it enables the irrigator to apply the exact amount of water to achieve the goal. This increases irrigation efficiency. Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizer. It allows irrigations to be coordinated with other farming activities including cultivation and chemical applications.

FAO (1989) explained that when surface irrigation methods are used, however, it is not very practical to vary the irrigation depth and frequency too much. In surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all the time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval, to keep the irrigation depth and the interval constant over the growing season. Of several methods to determine *when to irrigate*, Water budget method is is more commonly applied these days. The water budget technique is based on the equation:

$I = ET - Pe + ROi + DPi + L + Drz(\theta f - \theta i)$..3.12

Where: I= Irrigation requirement; ET= evapo-transpiration; Pe= effective

Precipitation (cm); ROi,= runoff due to irrigation (cm); DPi= deep percolation

Due to irrigation (cm); Drz= depth of root zone (cm); Qf& Qi = final and initial

Soil moisture contents. Soil based irrigation scheduling involves determining the current water contents of the soil, comparing it to a predetermined minimum water content and irrigation to maintain soil water contents above the minimum level. A soil indicator of when to irrigate also provide data for estimating the amount of water to apply per irrigation. Thus, irrigation interval is calculated by the formula;

IR=AMD/ETC where:

AMD= allowable soil moisture depletion, cm

ETC= daily water use, cm/day

4 .RESULTS AND DISCUSIONS

4.1 Comparative performance indicators

4.2.1 Agricultural output performance indicators

These indicates performance indicators that is associated with the productivity .the major of such performance indicators includes; output per unit cropped area ,output per unit irrigation supply and output per unit cropped area.

4.2.1.1 Output per unit irrigated cropped area (OPUI)

By using equation 3.6 and appendix table 15; the output per cropped area is 1465450/79 18550.0 birr/ha and 1065600/66 gives 16145.45 birr/ha for Bobe and Laku respectively for the year 2007.

For the outputs per unit cropped area of the value of crop production with project situation 5097.73 and 2292.3 birr per hectare for Bobe and Laku respectively concludes that, the income per cropped area at Bobe is better productive than Laku scheme, these is due to proper management for Bobe irrigation scheme.

4.2.1.2 Output per unit of command area (OPUC)

This is the value of agricultural production per unit of nominal area which can be irrigated**.** It also an indicator which articulates the average returns per design command area. It is an indicator of whether all the command areas are generating returns or not.

From equation 3.7 the output per command area is 22203.8 birr/ha and 23680 birr/ha for Bobe and Laku respectively, for year 2007.The irrigated area for Laku was 45 ha and that of Bobe was 66 ha.we can calculate for the year 2007/2008 within the same procedures for 2007.an average income rate is increasing in 2007/2008 which implies that the output per command area and cropped area is increasing. .

4.2.1.3 Output per unit irrigation supply (OPUIS)

The outputs per unit irrigation supply show the revenue from agricultural output for each meter cube of irrigation water supplied. It tells as how well the total annual diverted irrigation water from source is productive .irrigation water supply includes conveyance losses in canals in areas where water is scarce, water management aims to increase the output per drop of irrigation water.

The total amount of water pumped by each project during the crop growth period was estimated based on the output per second of the pump, the number of pumps used, duration of operating hours each day, and total days taken by crops to mature.

By using equation 3.8 the output per irrigation supply is 3.26 birr/m^3 and 1.45 birr/m^3 for Bobe and Laku in the year 2007 and 2008.

4.2.1.4 Output per unit irrigation water delivered (OPIWD)

This indicator gives due attention to the water consumed by each scheme and tells us how water is efficiently utilized by the scheme from economic point of view. This means for the value of production per unit volume of annual irrigation water delivered to the head of command area. It is different from irrigation supply as it does not include losses in conveyance system. It is a useful comparative indicator because it addresses output per drop of water irrigation actually delivered to the user. By using equation 3.9 and appendix table 15 of column 2 and; the output per unit irrigation water delivered is 6.8 birr/m^3 and 8.95 birr/m^3 for Bobe and Laku respectively.

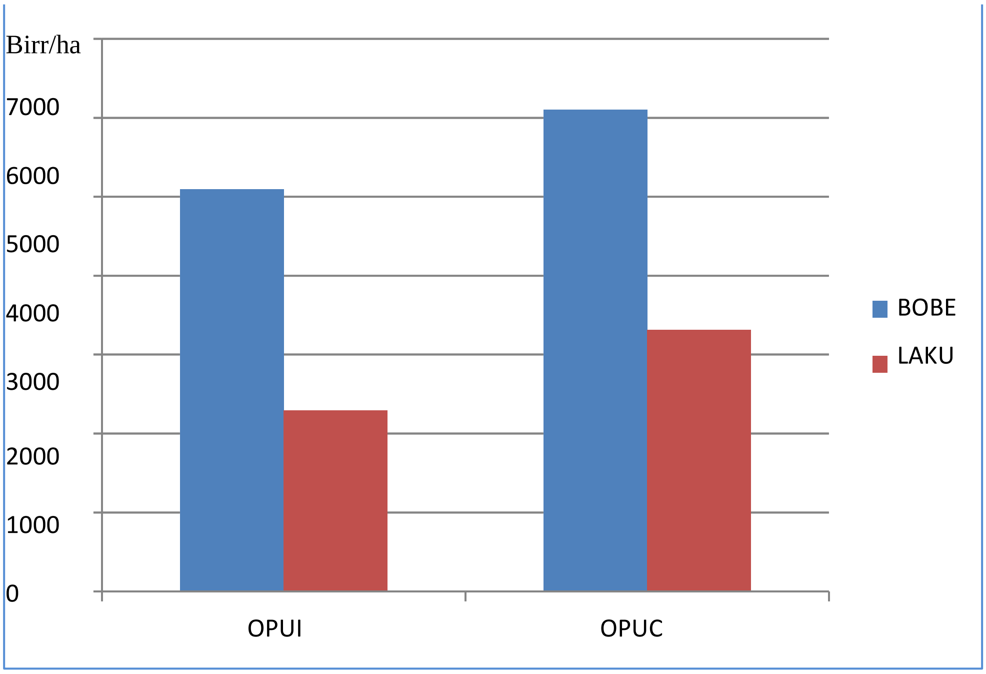

Figure 5: variation of productivity per area

The output per unit cropped area shows the response of each cropped area on generating gross return. The response or income per cropped area at Bobe is better than Laku irrigation scheme this is mainly due to the improvement of irrigation management in Bobe scheme this can be associated with the input use and strong institutional set up at the Bobe irrigation scheme. The output per unit command area indicates the average return per design command area.it is an indicator of whether all the command areas are generating returns or not. The irrigated area for Bobe was 66 ha and that of Laku was 45 ha. When this area is compared to each designed command area, Bobe irrigation scheme is 83.54% of the command area is irrigated or 13ha is under irrigation but in the Laku irrigation scheme, only 68.18% or (20ha) of the command area under irrigation. The detail expirations are shown in appendix Table.

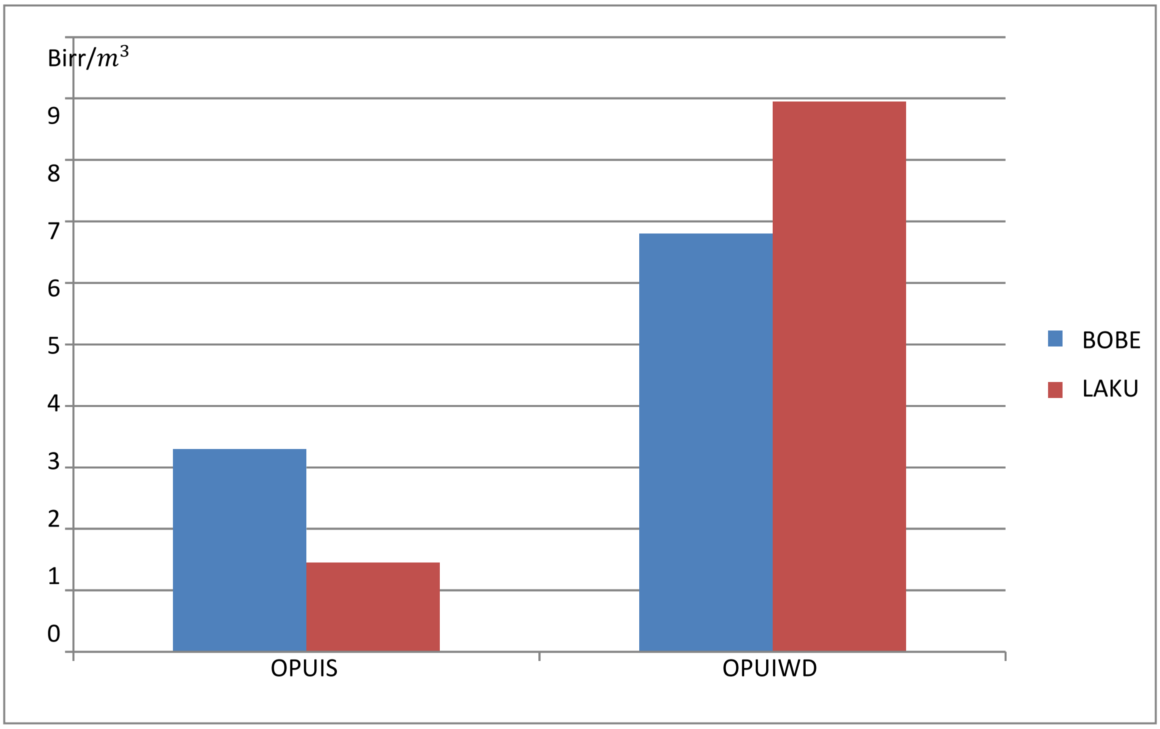

Figure 6: Variation of productivity per water supply

The output per water supply depicts that the Bobe irrigation scheme, the response of crops per cum.meter of water is better as compared to Laku irrigation scheme. This might be due to the excess supply of water beyond crop requirement to fields at Laku irrigation scheme than Bobe Moreover use of inputs also affects the returns from the irrigation schemes. The outputs per water delivery for Laku irrigation scheme are better than Bobe irrigation Scheme. This result shows that the water use efficiency is better at Laku than at the Bobe irrigation scheme. The reason for this may be institutional set up of Laku which is stronger than at the Bobe irrigation scheme

4.2 Water use performance indicators

4. 2.1 Relative water supply

The relative water supply describes whether there is enough irrigation water supplied or not to the command area. Both the relative water supply and relative irrigation supply relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand is matched. The relative water supply value below one normally indicates that the water applied is less than the crop demands and values above one indicate extra water is added to the root zone beyond plant demands. It gives a sound comparison between irrigation schemes with different rainfalls, because gross water supply was considered. From appendix table2 and 12 and equation 3.1; RWS is calculated as follows.
CWR potato*(AREAOF potato)/total area+……CWR maize*AREA of maize/Total area

From above formula the calculation implies the result of $362{,}074.02m^3$/season by using the same procedure IR gives $392{,}647.20m^3$/season. The relative water supply of Bobe irrigation scheme was found to be 2.3 and that of the Laku scheme was 2.1, from definition of water supply for greater than one RWS indicates that excess water was used beyond plant demands in both schemes but the case of Bobe scheme, is relatively higher than that of the Laku scheme. In order to maximize water use efficiency of the scheme, it is required that the amount of water supplied be reduced in both schemes.

4.2.2 Relative irrigation supply

The relative irrigation supply shows whether the irrigation demand is satisfied or not. This means that for the value of production per unit volume of annual irrigation water delivered to the head of command area. It is different from irrigation supply as it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. Inefficient water use results in lower values of this indicator.

From equation 3.2 and appendix table 2 and table 12&13 the RIS for Bobe and Laku is 1.92 and 1.75 from the result we deduce that RIS values are greater than RWS values for each of the two schemes .it implies that, irrigation is the major source of water supply for agriculture in the area. It can be observed that the RIS values for two irrigation scheme are higher than unity (1), which indicates that disregarding the distribution of the supply over the months excess irrigation water is being supplied.

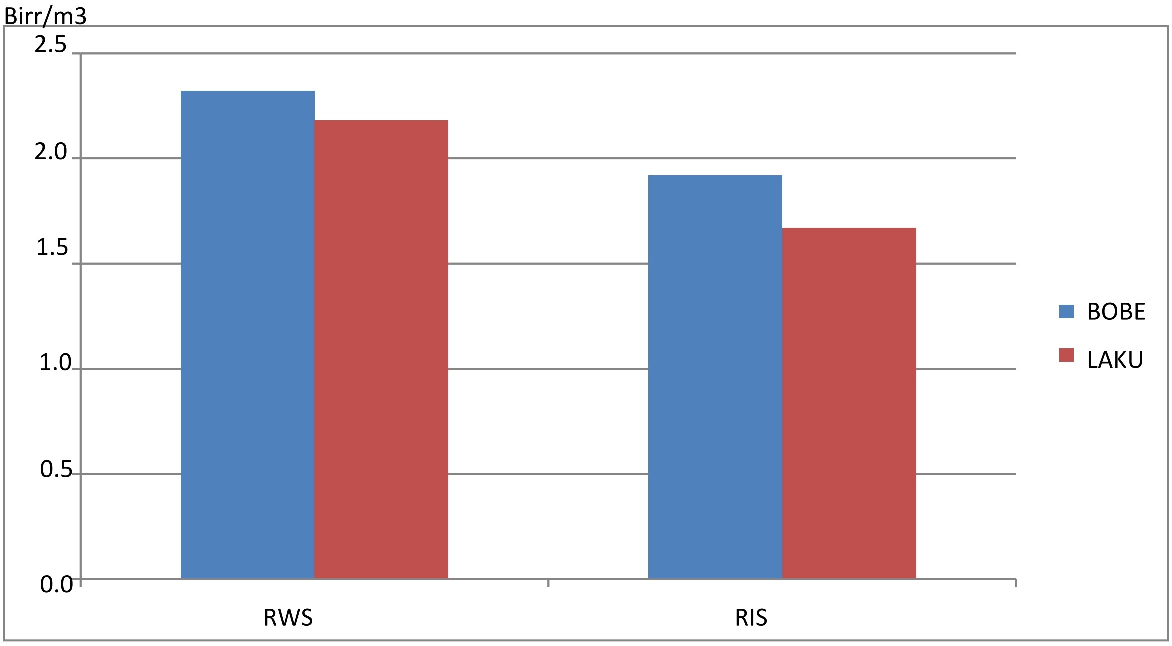

Figure 7: water supply indicators

The peak irrigation requirements of Laku irrigation based on cropwat model of months June to oct/dec cropping season occurred in sep value is 5.1 mm/dec. This is for continuous flow, and for 10 hours pump running time in a day then the peak consumptive demand will be: 5.1*
45* 2.40 =550.8mm/dec the peak irrigation requirement (5.51cm/dec) was determined for the irrigated area of 45 ha. The actual discharge capacity of the main canal at the system head was 158 lit/sec/ha, which was the total discharge of the two pumps. This value was taken because for the Laku irrigation projects the limiting factor to satisfy the water. From equation
3.4 a water delivery capacity (WDC) is 0.3. By following the same step the WDC of Bobe irrigation scheme is 1.57. The value of WDC at Laku is less than 1, so the capacity of the pumps at peak time of crop demand is below the requirements. The capacity of the pumps is in constraint to meet the maximum crop water requirement. The WDC of Bobe irrigation project is higher than 1, so the canal capacity is not a constraint to meet crop water demands. Values close to 1 indicate that there may be difficulties meeting short-term peak demands (Molden et al, 1998).
The gross investment cost per hectare of each irrigation projects were calculated for the actual irrigable areas of the projects rather than the developed irrigable area. Because even though the total irrigation areas developed were 272 ha and 69 ha, the actual irrigable areas were by far less than these values i.e. only 66 ha for Bobe and 45 ha for Laku. If the developed areas were considered for the investment and the total production calculated were from the actual irrigable land

the conclusion would be erroneous and lead to unrealistic decision.

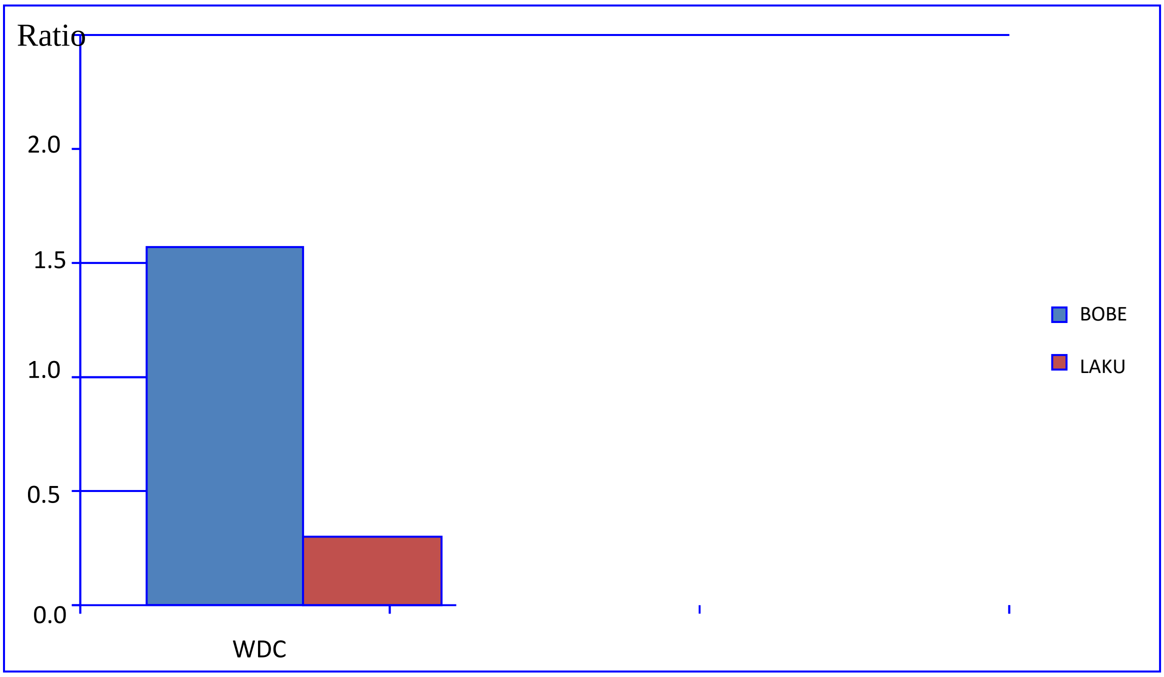

Figure 8: Spatial variations of water supply indicators

When we see the results of water supply indicators(RWS,RIS and WDC) of each irrigation project above the values of RWS and RIS higher than two .This higher values indicates that there was a generous supply of water and the sole water provider irrigation, no contribution of rainfall.

The value of WDC at Laku is less than 1.so the capacity of the pumps at peak time of crop demand is below the requirement. The capacity of the pumps is in constraint to meet the maximum crop water requirement. The WDC of Bobe irrigation project is higher than 1, so the canal capacity is not a constraint to meet crop water demands. Values close to 1 indicate that there may be difficulties meeting short-term peak demands (Molden et al, 1998).

4.3 Physical sustainability performance indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons.

4.4.1 Irrigation ratio

This is the ratio of currently irrigated area to irrigable command (nominal) area. It tells the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinity/water logging, etc, could result in underutilization of land. On the other hand, cropping intensity, a ratio of annual cropped area to nominal area is indicative of annual land utilization.

Irrigation ratio =irrigated area /command (nominal) area

Table 5: Physical performance indicators

scheme	Irrigable land(ha)	Initial irrigable land(ha)	Currently irrigable land(ha)	Irrigation ratio	Sustainability of irrigation area
Bobe	272.25	66	79	0.3	1.2
Laku	65	45	40	0.62	0.89

According to data collection from Holota research center three different sizes of land related to the scheme is collected to evaluate the physical indicators; such as irrigable land and currently irrigable land. The irrigable land of two schemes is determined from irrigable crop production .The initial irrigation areas when each scheme is commissioned is taken from project reports and the same confirms from local agencies .However, data from design reports may not exactly imply the irrigation areas, because the whole design area may not have been fully irrigated when the scheme is commissioned.

Irrigation ratio is an indicator for the degree of utilization of the available land for irrigation agriculture could also be a useful indicator for whether there are factors contributes for under irrigation of command area. Irrigation ratio is higher for Laku is higher than Bobe i,e 62%of irrigable command area. Higher irrigation ratio at Laku is due to three factors; munificent water viability, absence of irrigation water fee and better land productivity which encouraging farmers to invest on more areas. Lower irrigation ratio at Bobe is attributed to lower reliability of irrigation flows during the same months of the year.

4.4.2 Sustainability of irrigated area

Sustainability of irrigated area which tells on whether the area under irrigation is contracting or expands right from the commencement of the scheme till date is a useful indicator for sustainability of irrigation. Bobe and Laku have more or less similar values, 1.2 and 0.89, respectively, implying reduction of irrigated areas by about 11% for Laku. For Bobe Scheme with a value of 1.2, the irrigated area has expanded by about 20% since commissioning. Same reasons for irrigation ratio, namely, more reliability of irrigation water flow, absence of irrigation water fee and better land productivity are the contributing factors for the expansion. These factors encourage more farmers to come to the area and irrigate lands by leasing or renting from local land owners.

The sustainable of irrigation area is the ratio of currently irrigated area to initially irrigated area when designed (Bos, 1997).It is useful indicator for assessing the sustainability of agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation:

Sustainability of irrigated area=currently irrigated area/initially irrigated area

4.4 Economic performance indicators

4.4.1 Gross return on investment

The gross investment cost per hectare of each irrigation projects were calculated for the actual irrigable areas of the projects rather than the developed irrigable area. This indicator considers the production and the total cost of infrastructure for each scheme. even though, the total irrigation areas developed were 65 ha and 79 ha, the actual irrigable areas were by far less than these values i.e. only 45 ha for Laku and 66 ha for Bobe. If the developed areas were considered for the investment and the total production calculated were from the actual irrigable land the conclusion would be erroneous and lead to unrealistic decision.

As example the Bobe GRI is computed by using the following formula which follows the same step for Laku scheme.

4.4.2 Investment costs

This cost includes costs required for construction of the project; headwork and irrigation infrastructures, small farm tools, drainage works and crop protection spray equipment's. Here the major cost is project investment costs, which includes

Table 6: Investment cost for Bobe scheme

No	Work Item	Cost (ETB)	% Cost	Comm. Share	Community (%)
1	Access road, Camping & Mobilization	266811.42	4.64	574,404.6	10
2	Head Work	481072.45	8.37		
3	Canals and other irrigation infrastructures	5012162.51	87.25		
4	Grand total project cost	5760046.38	100		
5	Cost per hectare		87,031		

4.5 Operation and maintenance cost

Under this analysis the operation and maintenance costs consists of Maintenance cost of major civil work, cost of materials for repair and of tertiary irrigation and drainage system and maintenance cost of infrastructure. So that under this case operating and maintenance cost 2% of the total investment cost were taken for the analysis.

Gross return on investment = Gross production / Costs of investment

6103.03 / 115200.93 = 5.3%

Table 7: Investment cost for Laku scheme

Types of costs	**Amount of money**
Initial investment cost	62684.68
Operation and maintenance cost	19477.55
Total	85162.23

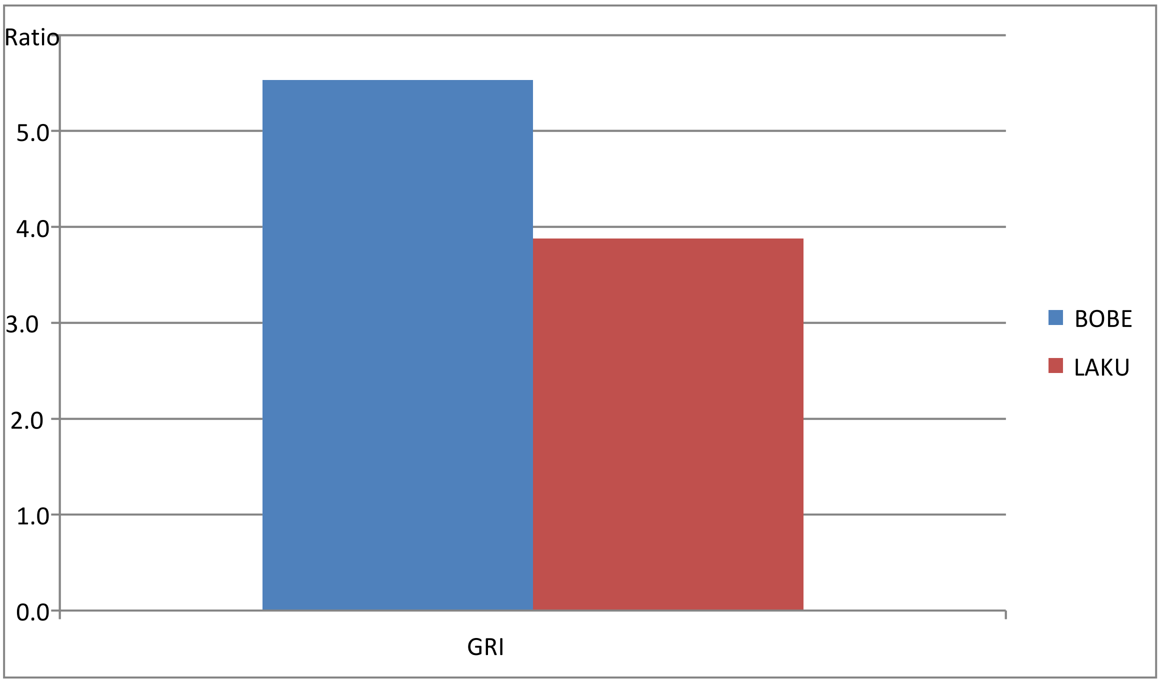

Figure 9: Economic performance indicators

GRI of the projects are 5.3% and 3.88% for Bobe and Laku, respectively. These values indicate that Bobe has higher rate of return on investment than Laku irrigation scheme. The possible reason for lower GRI value of Laku is that large irrigable area is reduced from the project due to low pump capacity. The water distribution structures of the project are designed and constructed for 65 ha land but the actual irrigable area is only 45 ha.

4.6: Financial self sufficiency

Financial self-sufficiency indicates the ratio of revenue from the irrigation to the expenditure for operation and maintenance. It shows the compensation ratio of management and maintenance Costs for irrigation system based on the income obtained from the irrigation. This in other words Implies the sustainability of the schemes, and perception of the farmers towards the irrigation Scheme. From the following table the value of FSS for Bobe and Laku is 3.5 and 1.75 respectively.

Table 8: Bobe trend of FSS for the year 2008

Ser no	**Crop type**	**Price per quintal**	**Yield/ha**	**Area (ha)**	**Revenue (birr)**	**Financial self sufficiency (%)**
1	Potato	400	200	26	2080	
2	Garlic	1000	50	13	650	
3	Cabbage	350	110	7	269.5	
4	Beetroot	500	60	7	210	
5	Onion	700	90	13	819	
Total				66	4028.50	3.5

Table 9: Laku trend of FSS for the year 2008

Ser no	**Crop type**	**Price per quintal**	**Yield/ha**	**Area (ha)**	**Revenue (US$)**	**Financial self sufficiency**
1	Potato	400	100	16	640	
2	Garlic	1000	30	8	240	
3	Cabbage	350	80	5	140	
4	Beetroot	500	40	6	120	
5	Onion	700	50	10	350	
Total				45	1490	1.75

4.8 Running the SIRMOD III Software

Sirmod III is comprehensive software packages used to simulate the hydraulics of surface irrigation systems at the field levels. The software is based on the full hydrodynamic model, but is capable of applying the volume balance model to determine the infiltration characteristics of an irrigated furrow.

This application selects the combination of sizing and operational parameters that maximizes application efficiency a two point solution of the inverse problem allowing the computation of infiltration parameters from the input of advance data.

4.9.1 Bobe irrigation scheme output

Four farmers' fields were selected in order to compare water use efficiency, for the safety and input of software analysis average observation of field data were used. According to my observation and data collected from research center our observation of the soil textural classes is dominated by Clay loam. The soil structure of project has good workability, good drainage characteristics, not sensitive to erosion and has no any limitation for irrigation development. According to furrow modeling of continuous flow Kimberly estimates 5% of slopes for clay loam soils on the field.

Effective soil depth is the depth of the soil at which normal crop roots growth is limited and affected by the presence hardpan, toxic, compacted layers, rocks or gravel layer and high water table. The project area has medium to deep depth at the head of the command area and deeper from middle of the command to the tail.

The field length and width is about450m by 250m respectively, the maximum furrow length in the field of the selected irrigation scheme is about 10m and the furrow layouts in irrigation fields were not straight line these was to avoid from soil erosion, so that it may be slight curved or branched to the opposite inflow direction of the initial furrow stream. The average size of top, middle and bottom of the furrow is 0.36m, 0.28m and 0.22 m respectively. The maximum depth of the furrow is 0.5m. The total available flow is 53.4 l/s from *appendix table 11*. The design flow for furrow is 0.52 l/s by using Qmin from *appendix table 11* per furrow within the cutoff time 450minute (tco=td-AoL/2Qo) cutoff time is equal to depletion time minus cross sectional area divide by twice of inflow discharge .cutoff time is when water flow at the inlet to the field is shutoff, the water on the surface will drain or recede from the field.

The farmers prefer cabbage for high production; the crop requires a cool, humid climate. The length of the total growing period varies between 90 and 200 days. Depending on climate, variety and planting date, but for good production the growing period is about 120 to 140 days. Most varieties can withstand a short period of frost Heavier loam soils are more suited to cabbage production. Under high rain fall conditions, sandy or sandy loam soils are preferable because of improved drainage. Cabbage is moderately sensitive to soil salinity.

Water requirement vary from 380-500 mm depending on climate and length of growing season.

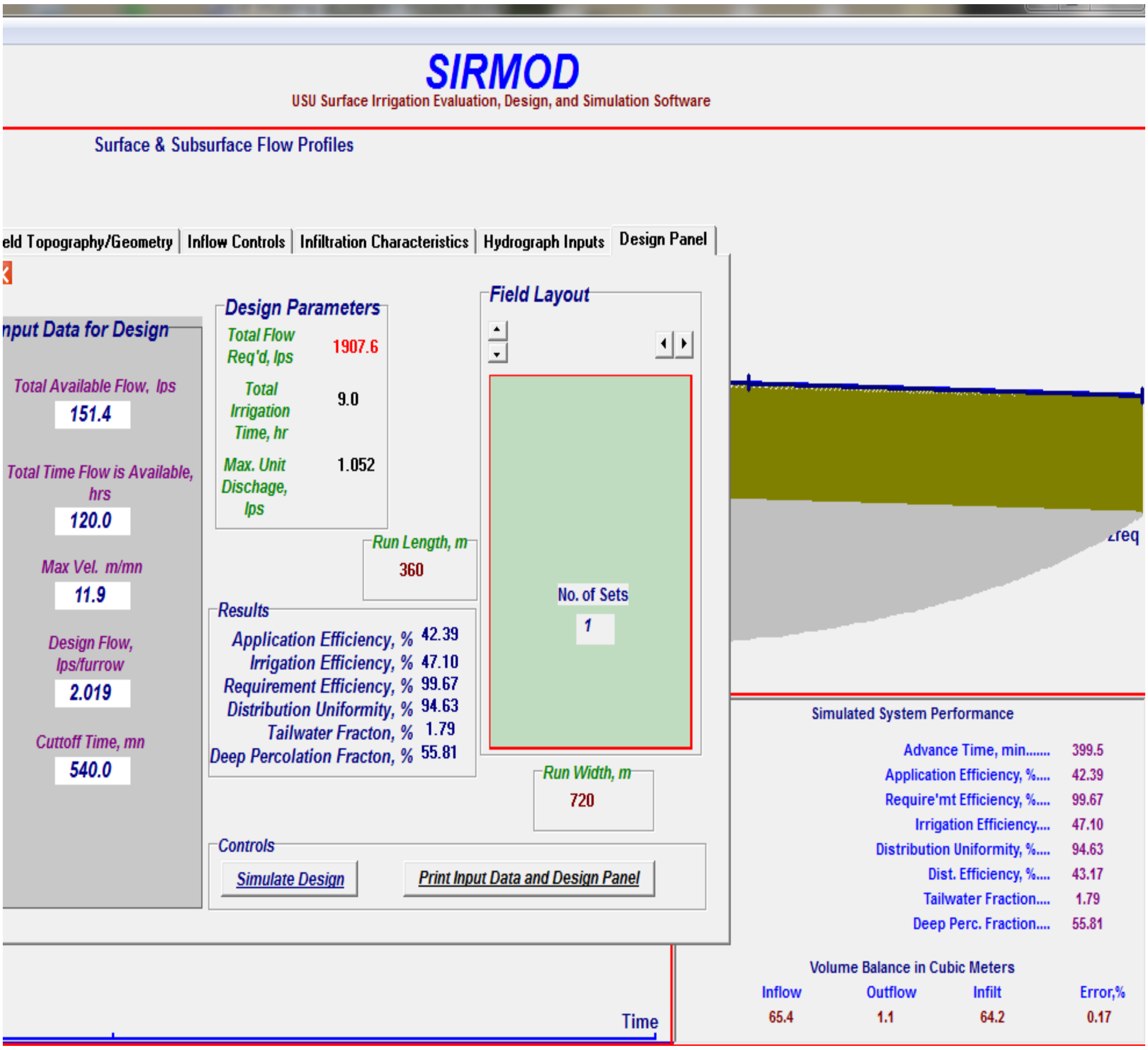

Figure 10: Simulate design panel of Bobe scheme

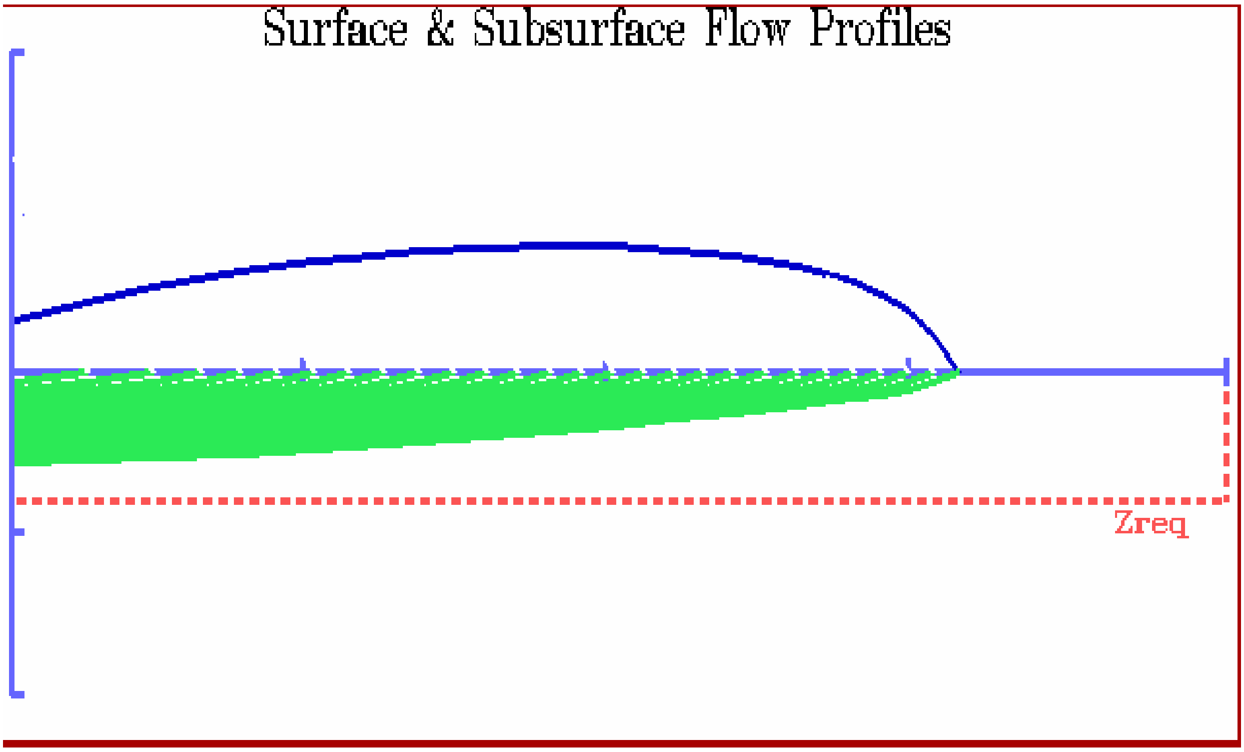

Figure 11: Simulation design profiles of surface &subsurface for Bobe

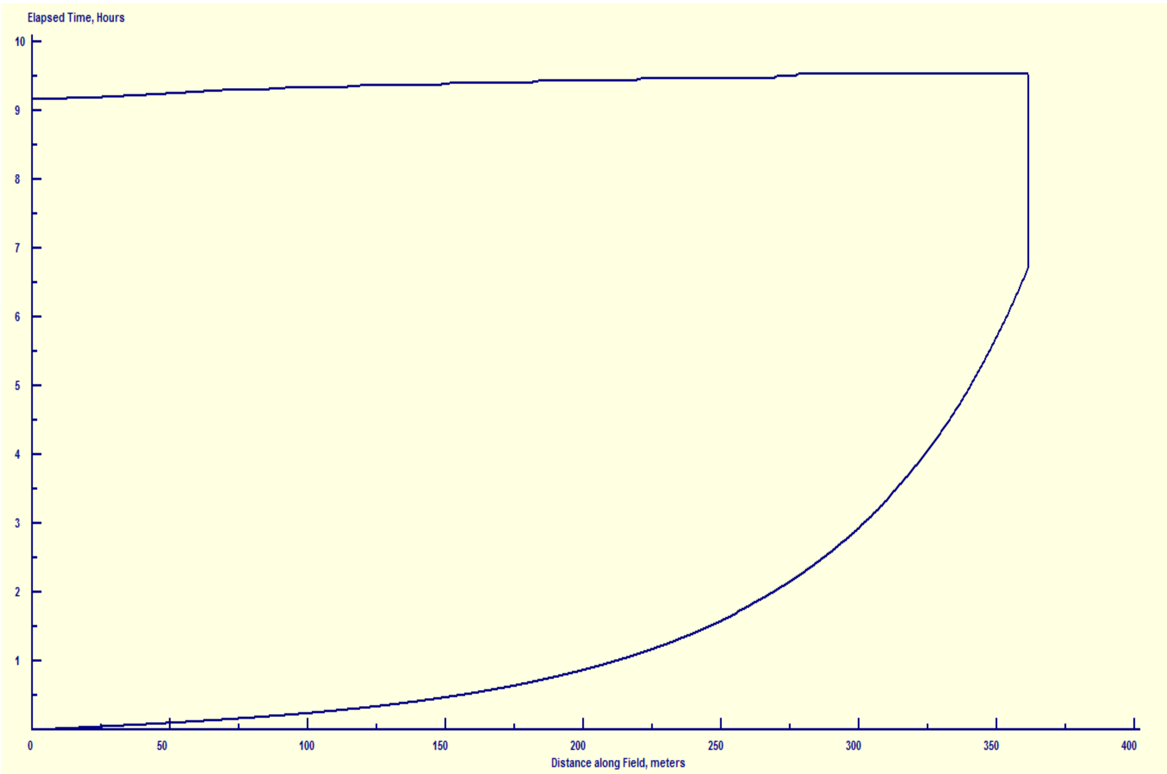

Figure 12: Advance Data of Bobe

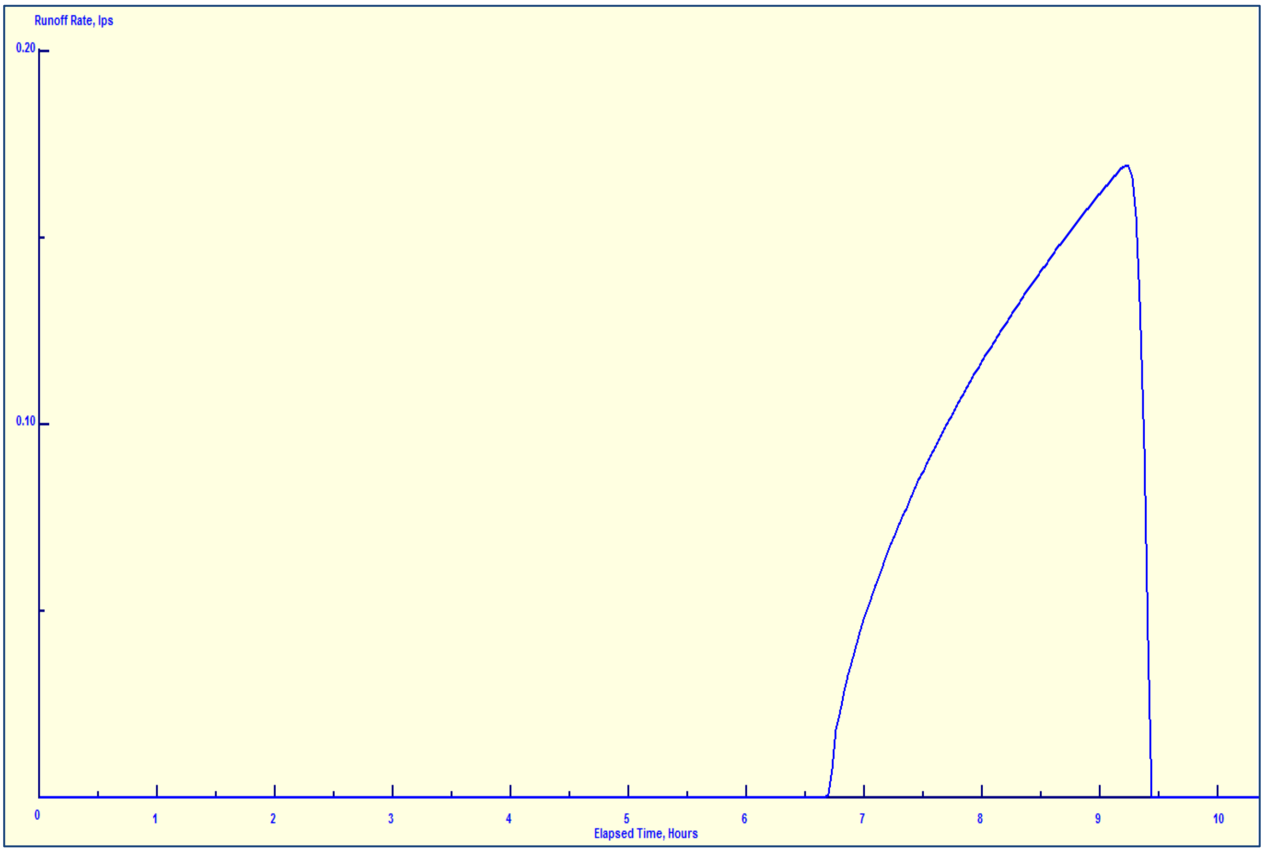

Figure 13: Tail Water Data of Bobe

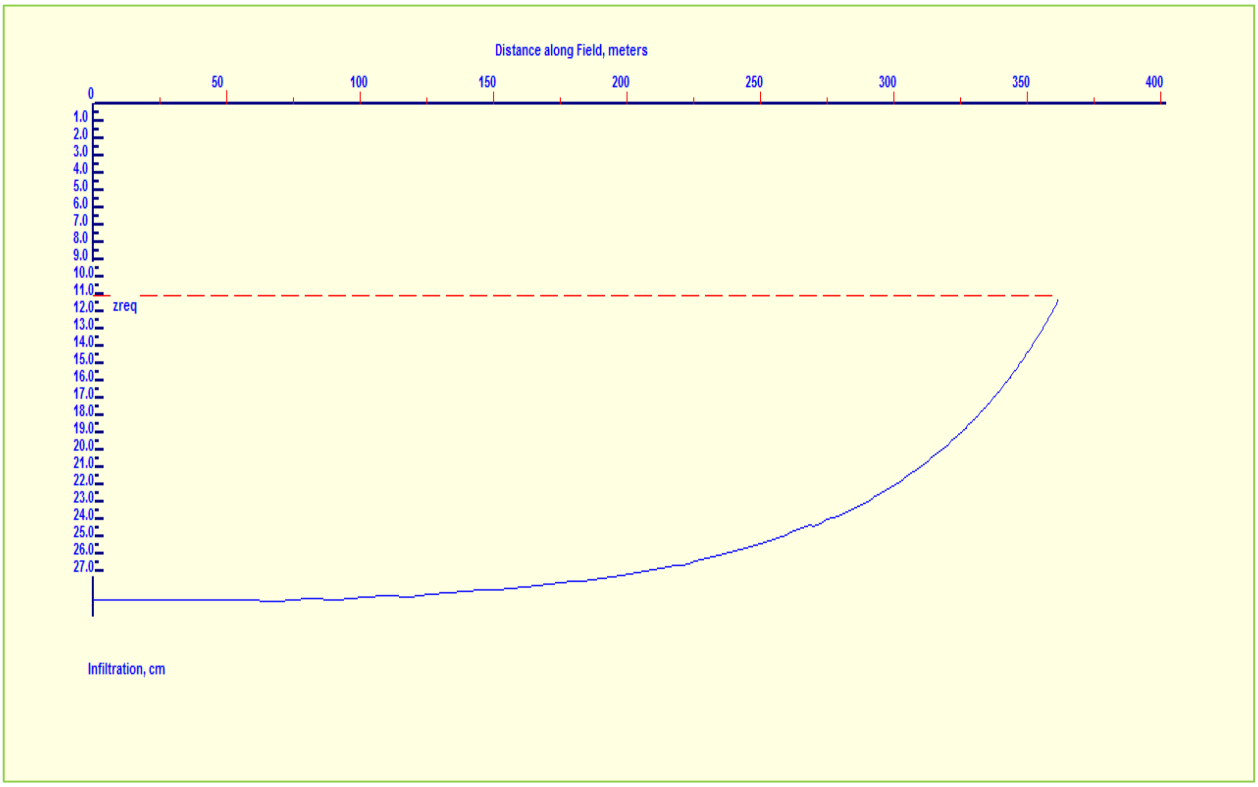

Figure 14: Applied Depth Data of Bobe

4.9.2 Laku Sirmod III software analysis

In this types of field irrigation system water user was grouped into four groups .according to these association and their agreements the management was carried out rotation by rotation. Farmers have the right to irrigate their fields at any time and the amount they feel the crop needs based on the rounds .the rotation irrigation interval may varies from5 to 8 days. There was no variation of water availability from upstream to the downstream farmer's irrigation fields. The discussion of these groups were very interesting, they solve the differences between them by negotiation .the input data used for surface irrigation evaluation, design and simulation software analysis, the available total flow is 283.2l/s.

From figure 4.11 the water is being added to the field and is advancing. By using Data gathering from the field and empirical parameters the input data uses for field geometry, inflow controls, infiltration characteristics and hydrographs. This gives an output of application efficiency, irrigation efficiency, distribution uniformity, requirement efficiency or storage efficiency and tail water fraction.

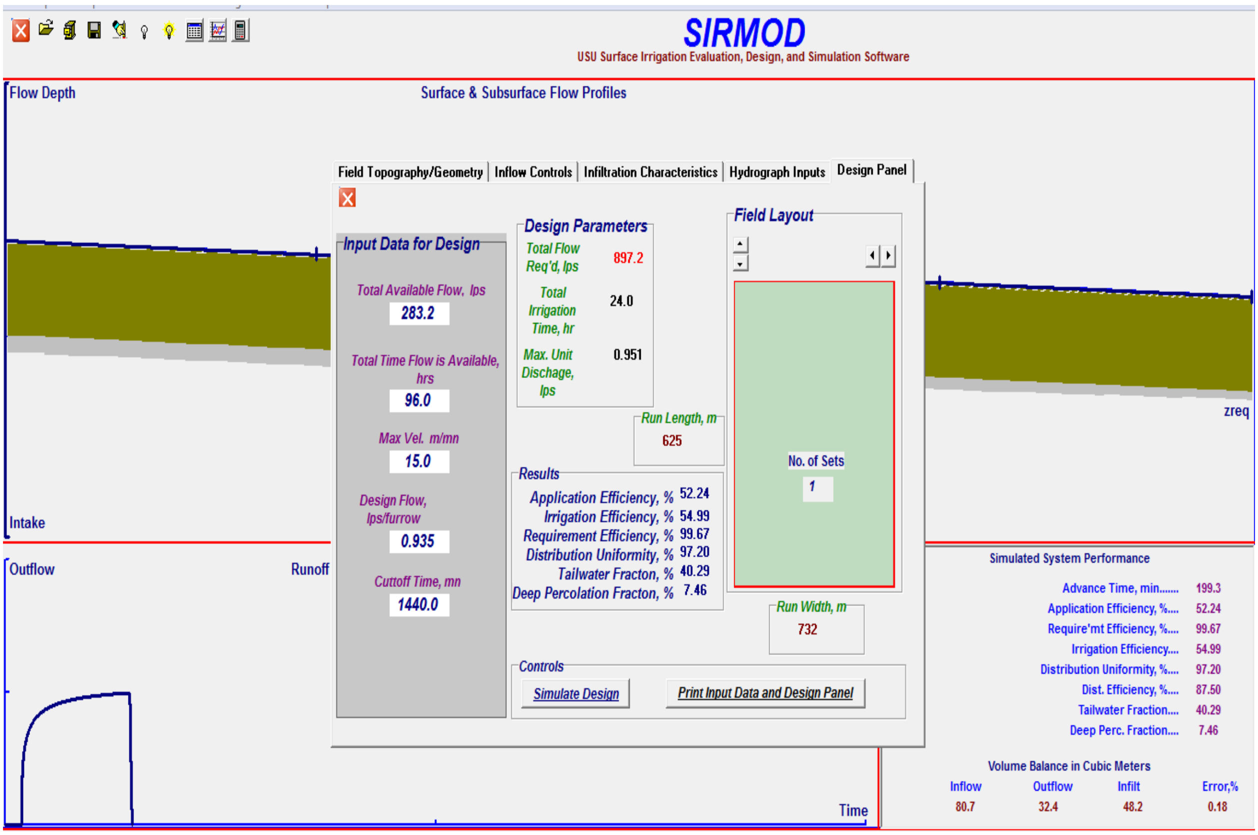

Figure 15: Simulation design panel of Laku scheme

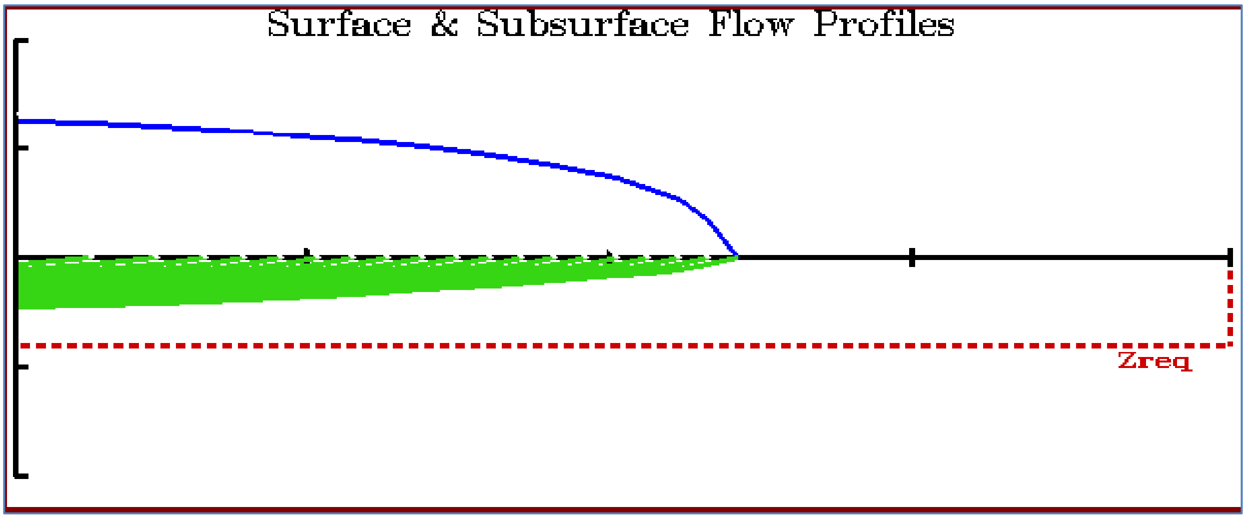

Figure 16: Simulation design profiles of surface and subsurface for Laku

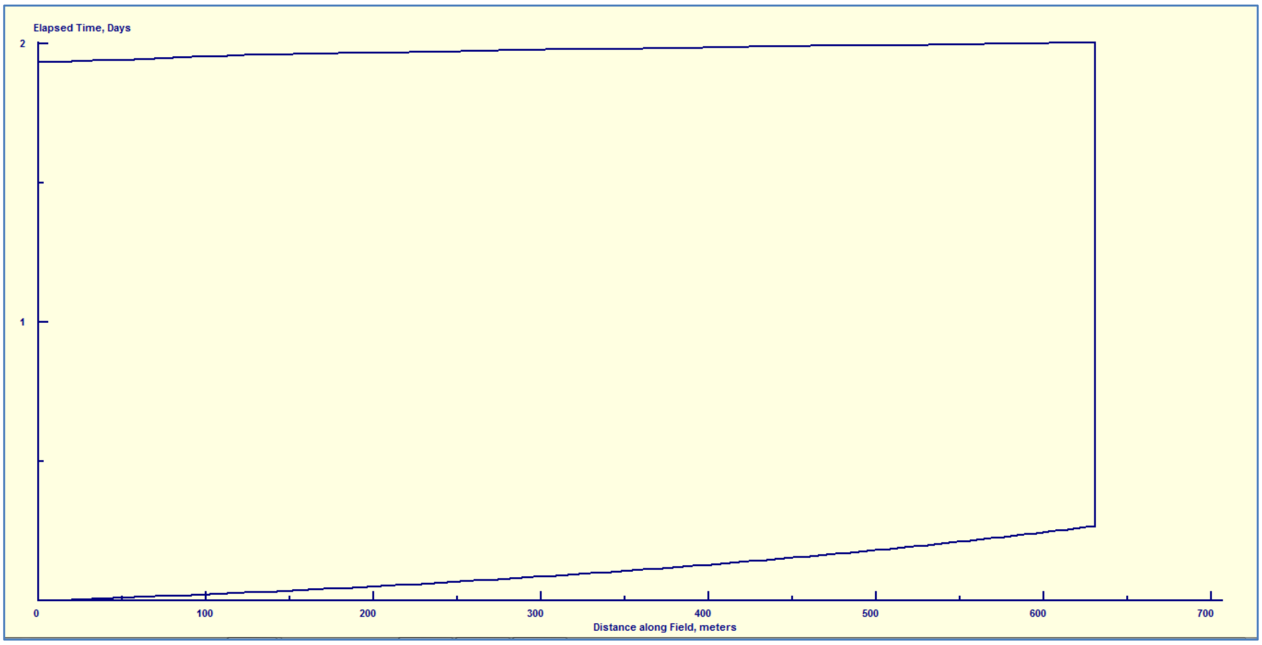

Figure 17: Advance data of Laku

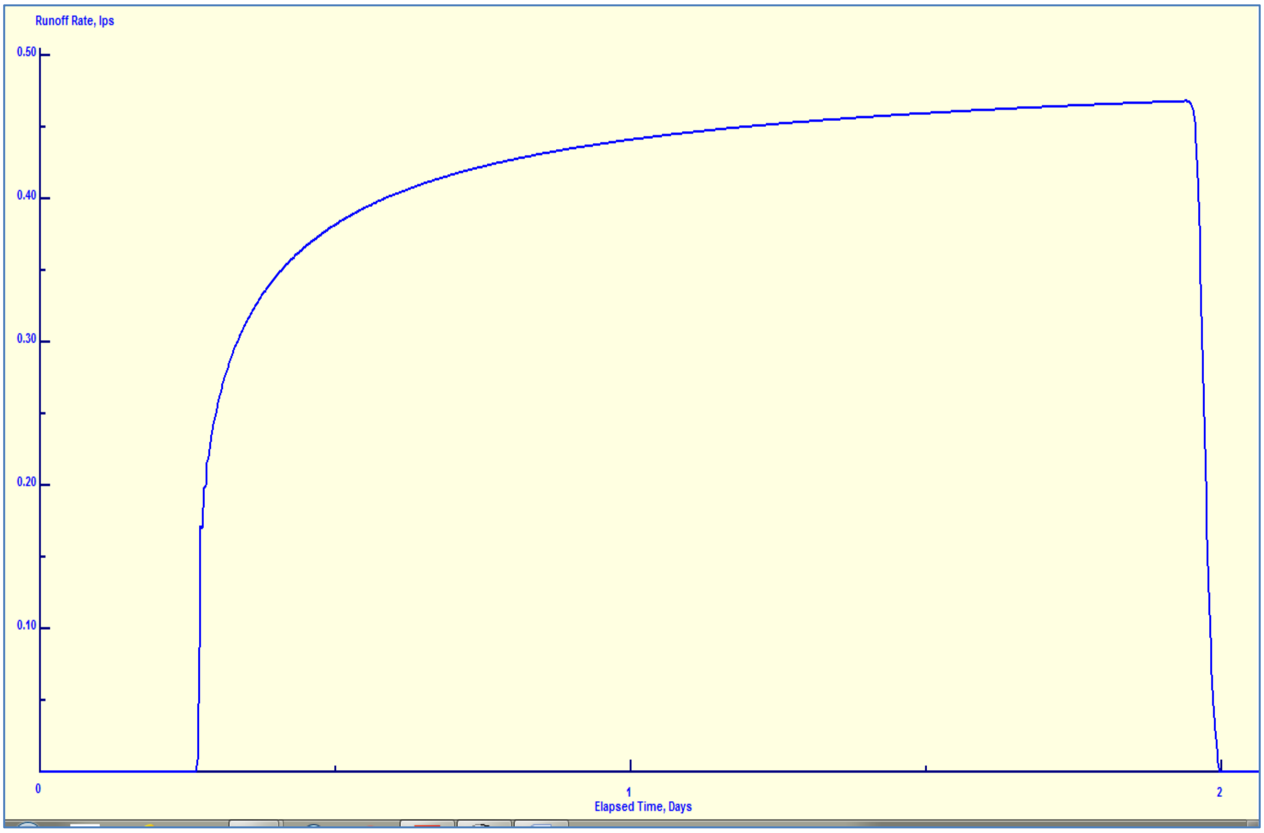

Figure 18: Tail water data of Laku

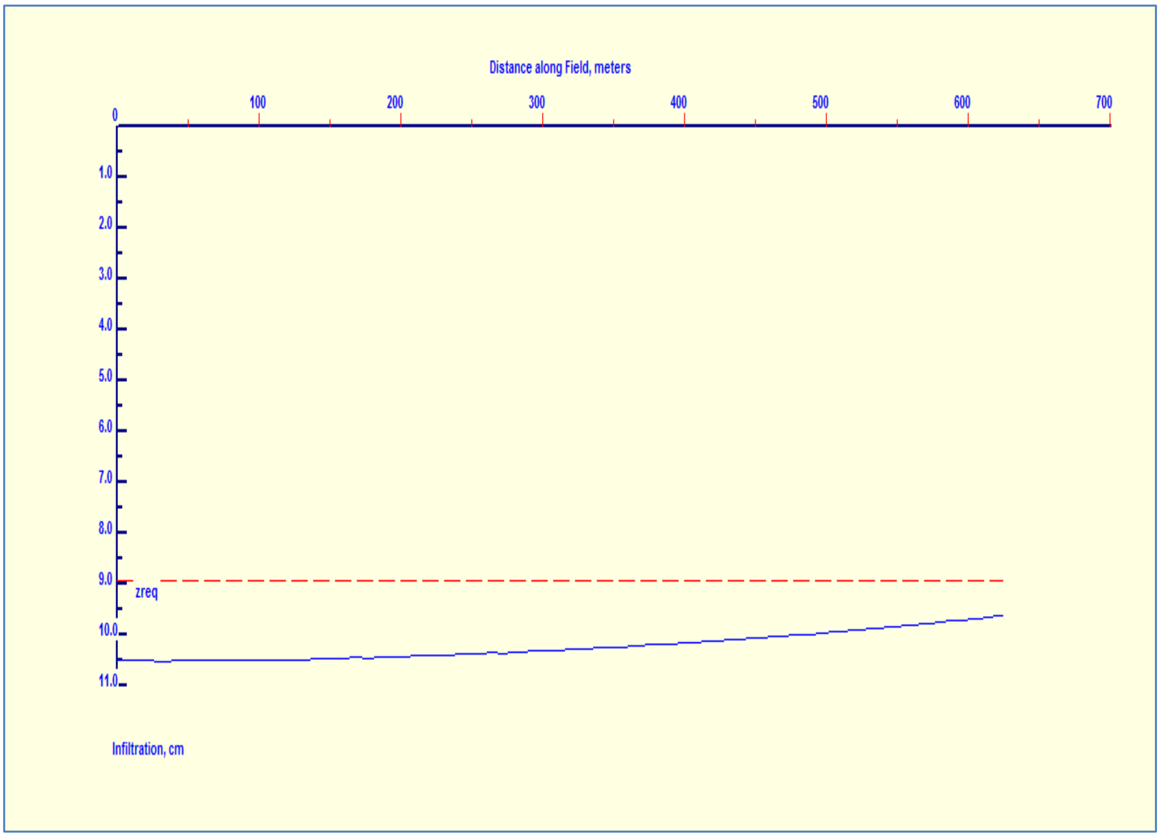

Figure 19: Applied depth data of Laku

4.9 Internal indicators result analysis

4.9.1Application efficiency (Ea)

The application efficiency of a given irrigation scheme tells us whether the irrigation water is stored in the intended soil profile or lost as surface runoff or/and deep percolation. The Application efficiency of selected fields at the Bobe irrigation scheme was found to vary from 63.28% to 85.80% with mean values of 73.46% but the same for selected fields at the Laku Irrigation scheme vary from 55.07 to 75.10% with an average application efficiency of 60.95%. The details of application efficiencies for the selected fields in both schemes are shown in Appendix Tables 20 and 21. The finding indicates that the application efficiency of Bobe irrigation scheme was better that of Laku irrigation scheme. This may be associated with the institutional set up of Bobe irrigation scheme which is stronger than that of Laku irrigation scheme. Generally the application efficiency of both schemes are typical results for furrow irrigation (Savva and Franken, 2002), which is recommended as 50-70% for properly designed furrow irrigation.

4.9.2 Requirement efficiency(Er)

The result of storage efficiency of selected fields from Bobe irrigation scheme was found to vary from 40.97% to 54.74% with an average storage efficiency of 47.57% and that of selected fields from Laku irrigation scheme varied from 38.60% to 50.34% with an average storage efficiency of 45.22%. The details of storage efficiency for selected fields and the average storage efficiency in both schemes are shown in Appendix Tables 20 and, 21.the storage efficiency at Bobe irrigation scheme was slightly greater than Laku, but in general the storage efficiency of both schemes were very poor as compared to 63% storage efficiency usually found in typical furrow irrigation systems (Raghuwanshi and Wallender,1998). This normally shows over irrigation of the field and this might be associated with the intention of the farmers on high return from high irrigation depth.

4.9.3 Distribution uniformity (Du)

When irrigation water is applied uniformly in a field it helps to get uniform crop stand and Uniform crop growth on the field. In this particular study the irrigation uniformity for Bobe varies from 96.3% to 98.4% with an average value of 97.44% and on the fields in Laku scheme it varied from 94.86% to 99.63% with an average of 96.64%. The details of irrigation uniformity are presented in Appendix Tables 8 and 9. The irrigation uniformities of both schemes were very good, which may be due to the short Furrow length commonly 10 meter,. The irrigation uniformity figures observed in both schemes of present study are much higher than the advanced furrow irrigation systems, which is 70% reported by Raghuwanshi and Wallender (1998) and the modern Amibara Project irrigation uniformity of 93% as reported by Kandiah (1981).

4.9.4 Deep percolation fraction

Deep percolation fraction implies that the irrigation applied to the field percolates into the soil below the root zone. High deep percolation values are indication of over irrigation. As we get the result from above fig 4.6 and 4.10 the deep percolation fraction of Bobe is 55.85% and that of Laku is 7.46%; by observing fig 4.9 and 4.14 of applied depth data, the water is infiltrated to the root zone of the soil for Bobe is much higher than laku.from the principle high percolation implies over irrigation so Bobe fulfill related to Laku.

4.9.5 Conveyance efficiency (Ec)

The conveyance efficiency value which indicates that, the amount of water lost during transportation of water from the diversion point or source to the field canal. The conveyance efficiencies of Bobe and Laku irrigation scheme were found to be 52.43% and 42.48%, respectively. The details of conveyance efficiencies for selected fields in both the irrigation schemes are shown in Appendix Tables 17 and 18.

The conveyance efficiency of the Bobe irrigation scheme is better than the Laku irrigation scheme. This is probably associated with main canals, secondary canals and tertiary canals management. In Bobe irrigation about 1.2km length of the main canal is lined and the farmers uses properly, the tertiary canals size is enough to convey the water and no over topping of water on tertiary canals. In the case of Laku irrigation scheme the main canal was unlined; certain over-topping of water in tertiary canals was happened. However, the values of conveyance efficiency for both schemes are below the recommended value i.e.70% unlined poorly managed main canals (MoAFS, 2002).

4.10.6 Overall Scheme Efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the Amount released at the headwork. In other words, it is the product of conveyance efficiency and Application efficiency. In the present study the overall efficiencies of the Bobe irrigation scheme is 38.52% and the overall efficiency of Laku is 25.89% .The details of overall scheme efficiency of both schemes were derived from the data shown in Appendix Tables the result indicated that the Bobe irrigation scheme was relatively good. The overall efficiencies of both irrigation schemes were outside the range of values (40-50%) commonly observed in other similar African irrigation schemes (Savva and Frenken, 2002).

5. CONCULISION AND RECCOMMENDITION

5.1 Conclusion

Bobe and Laku irrigation scheme projects are the two selected study area that are located in upper awash Basin. According to OIDA and Holota research center, the area is selected based on field observation, measurement of canal water flow at the diversion of Bobe and pumping discharge of Laku is taken by using primary field data collection.

The secondary data collection has been carried out by organizational set up, which includes total yield, farm gate prices of irrigation crops, area irrigated per crop per season or per year. Operation and maintenance generated by the irrigation area and command area at Bobe is higher than Laku, which implies that the irrigation practice in Laku was relatively poor and larger amount of command area was not under irrigation. These may due to farmer‟s economic capacity for buying crop protection, chemicals, fertilizers and high fuel price to pump water.

Comparative indicators are more useful when used for comparison where by better performances of one scheme could be bench mark to the others. This study will assists effort towards enhancing productivity and sustainable use of irrigation water in community managed scheme in the region.

The relative water and irrigation supply for both scheme shows that there is a high ratio, which implies the amount of water applied during irrigation events was much higher than that was required by crops. This type of irrigation affects the farmers by extra expenses in case of Laku. Due to pumping water using diesel fuel results higher cost of fuel price and wastage of water also happens while cultivating extra fields.

An output per irrigation area of the Bobe is about twice of Laku these is due to more irrigation practice in Bobe than Laku scheme. Higher output per irrigated area also indicates that the farmers invest more on their lands when reliability of water is high and when they get larger holding. The value of the output per command area of Bobe was also greater than the value of Laku irrigation scheme. The output per unit irrigation supply for Bobe was 2.08 while Laku was 3.31. Output per water consumed varies from 2.85 to 6.3 birr per m3 for Bobe and Laku respectively.

The gross return on investment of Bobe was better than Laku irrigation project and financial self-sufficiency of Bobe was also better than Laku irrigation schemes.

The control gates at both diversions are demolished for both of sub system of Bobe scheme (i.e.berfeta 1 and 2). The sluice gate is located at the off take of main canal for berfeta 1and on the structure part for berfeta 2(on the weir part) this is due to shortage of water during dry season no overflow.

Irrigation of Diversion weir (at Bobe) is better than Pump (Laku) for FMIS for its low operation and maintenance costs. As an opinion, advantage of Pump irrigation over Diversion weir was that the pump system can be used as a tool to force the farmers to improve or change their perception about irrigation water that it has costs and must be used efficiently. As physical indicator irrigation ratio shows that more areas of command.

In general, based on the assessment carried out, it can be concluded that the Bobe irrigation scheme performed better than the Laku scheme but it cannot be said the Bobe scheme does not need improvement so measures should be taken to improve the performance of both schemes. As there is no shortage of water, the schemes have room to expand and to provide irrigation opportunities to the surrounding community relying on rain fed agriculture. The comparison of the performance of irrigation systems will help to know the present status of these systems.

Increasing crop production and there by achieving food self-sufficiency and increasing farm income are the main output of this irrigation project. To fulfill these objectives, irrigable which are suitable to the soil and climatic conditions of the command area of the project, which have short life span and which can give good yield are proposed for the project. Production of two cropping season in a year (double cropping)is recommended , one as full irrigation (dry period irrigation) and supplementary irrigation during the rainy season. Crop system and management of proposed crop have been prepared.

5.2 Recommendations

Comparative indicators are very good estimator and indicator of performance of irrigation projects, reliable and consistent documentation system is a must. And this type of study has to be adopted and practiced on some other small-scale irrigation projects in the country.

In developing irrigation projects the capability of farmers to manage must be considered. According to the results obtained earlier water management practices of Laku was poor relative to Bobe .this however, can be improved by sharing experiences from Bobe and other well performing scheme. Therefore farmer's development agents (DAs) and concerned bodies of these systems better arrange visits to the sites for sharing their strong points on the other.

Additional pumps are required to rehabilitate the Laku irrigation project to its full productive capacity of irrigable area. Because about 65 ha of command area is under irrigation. For this and other reasons, designing and constructing irrigation projects have to be made with care and has to consider the capacity and knowledge of the farmers. Huge amount of money have been invested to construct the structures. And farmers are expected to use the water efficiently. Even though there was no sign of being unproductive from the time of the irrigation establishment, irrigation water was considerably wasted by the farmers themselves, especially at Laku.

Generally, agronomic recommendation given in the document should be followed by the development agents and the beneficiaries. Besides; the efficient use of command area (land and water resources) as proposed is very vital. To train the farmers particularly on the site and to strength irrigation extension, development of demonstration site on irrigation project is also very essential.

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7. APPENDEXIS

APPENDEX I .Tables

Appendix Table 1; Climate/ETO of potato for Bobe irrigation scheme

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\ts1.PEM

Country ETHIOPIA Station holota;2

Altitude 2508 m. Latitude 8.94 °N Longitude 43.27 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	8.5	23.1	53	80	8.3	19.8	3.51
February	8.1	23.7	51	86	7.1	19.3	3.72
March	7.3	24.1	54	84	7.3	20.5	3.94
April	10.5	23.7	65	94	7.8	21.5	4.06
May	11.1	25.1	60	57	7.0	19.8	3.84
June	10.3	22.3	56	47	2.8	13.3	2.81
July	10.7	20.4	73	56	3.6	14.5	2.82
August	10.5	18.5	81	43	5.5	17.7	3.09
September	8.6	20.8	84	50	8.3	22.0	3.69
October	7.4	23.0	78	88	9.3	22.7	3.93
November	6.5	19.7	58	76	8.9	20.8	3.45
December	6.2	18.9	54	74	9.1	20.4	3.20
Average	**8.8**	**21.9**	**64**	**70**	**7.1**	**19.4**	**3.51**

Appendix Table 2; data rain for Bobe scheme

Monthly rain - C:\ProgramData\CROPWAT\data\rain\ts2.CRM

Station: holota;2   Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	28.0	26.7
February	30.0	28.6
March	61.0	55.0
April	82.0	71.2
May	85.0	73.4
June	125.0	100.0
July	272.0	152.2
August	255.0	150.5
September	190.0	132.2
October	32.0	30.4
November	16.0	15.6
December	18.0	17.5
Total	**1194.0**	**853.4**

Appendix Table 3; climate/ETO of onion for Laku irrigation scheme

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\tk.PEM

Country: ETHIOPIA   Station: HOLOTA

Altitude: 2408 m.   Latitude: 9.02 °N   Longitude: 38.45 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	7.7	22.9	57	78	8.5	20.1	3.50
February	8.9	23.9	55	86	7.8	20.3	3.79
March	10.4	24.4	54	86	7.5	20.8	4.05
April	11.0	23.8	61	95	6.6	19.7	3.90
May	11.2	24.5	58	60	6.8	19.5	3.79
June	10.4	22.7	54	43	6.0	18.0	3.39
July	10.8	20.0	71	52	2.7	13.2	2.62
August	10.4	19.9	81	43	3.3	14.4	2.67
September	10.2	20.7	83	52	5.1	17.1	3.06
October	8.8	22.0	77	86	8.1	20.9	3.63
November	7.3	22.2	58	78	9.6	21.8	3.70
December	6.9	22.4	56	78	9.6	21.1	3.53
Average	**9.5**	**22.4**	**64**	**70**	**6.8**	**18.9**	**3.47**

Appendix Table 4; CWR for Bobe irrigation scheme

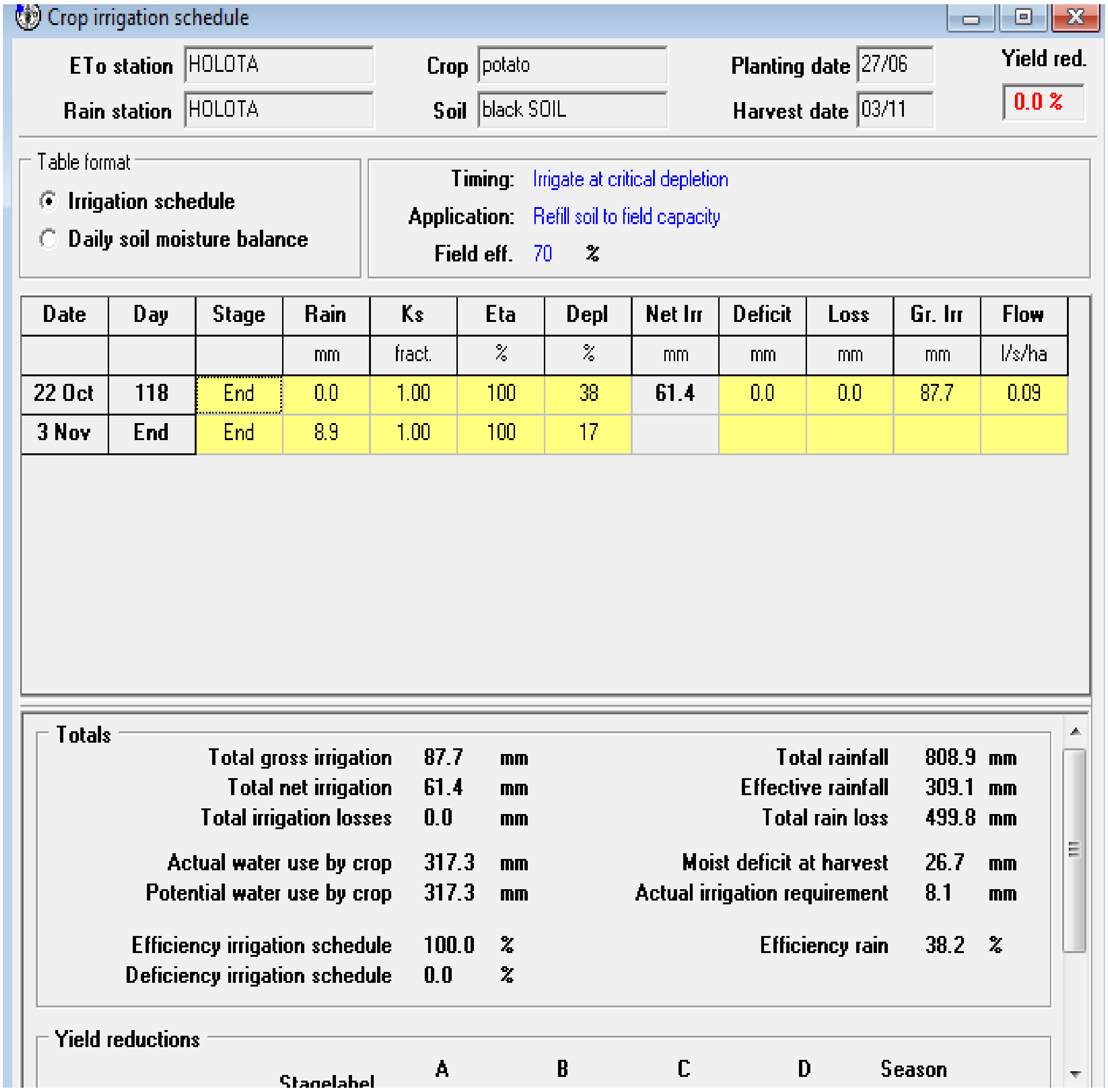
Crop Water Requirements

ETo station HOLOTA | Crop potato

Rain station HOLOTA | Planting date 27/06

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	3	Init	0.35	1.10	4.4	16.0	0.0
Jul	1	Init	0.35	1.01	10.1	47.0	0.0
Jul	2	Init	0.35	0.92	9.2	52.8	0.0
Jul	3	Deve	0.47	1.23	13.6	52.3	0.0
Aug	1	Deve	0.72	1.90	19.0	51.7	0.0
Aug	2	Deve	0.95	2.54	25.4	52.2	0.0
Aug	3	Mid	1.06	2.96	32.6	49.5	0.0
Sep	1	Mid	1.06	3.10	31.0	49.1	0.0
Sep	2	Mid	1.06	3.24	32.4	48.0	0.0
Sep	3	Mid	1.06	3.44	34.4	35.2	0.0
Oct	1	Late	1.03	3.55	35.5	18.4	17.1
Oct	2	Late	0.91	3.32	33.2	5.5	27.6
Oct	3	Late	0.78	2.86	31.5	4.8	26.7
Nov	1	Late	0.70	2.56	7.7	1.4	5.3
					319.8	**483.9**	**76.7**

Appendix Table 5; irrigation schedule of potato for Bobe scheme



Crop irrigation schedule

ETo station HOLOTA | Crop potato | Planting date 27/06 | Yield red.
Rain station HOLOTA | Soil black SOIL | Harvest date 03/11 | 0.0 %

Table format
- Irrigation schedule
- Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
22 Oct	118	End	0.0	1.00	100	38	61.4	0.0	0.0	87.7	0.09
3 Nov	End	End	8.9	1.00	100	17					

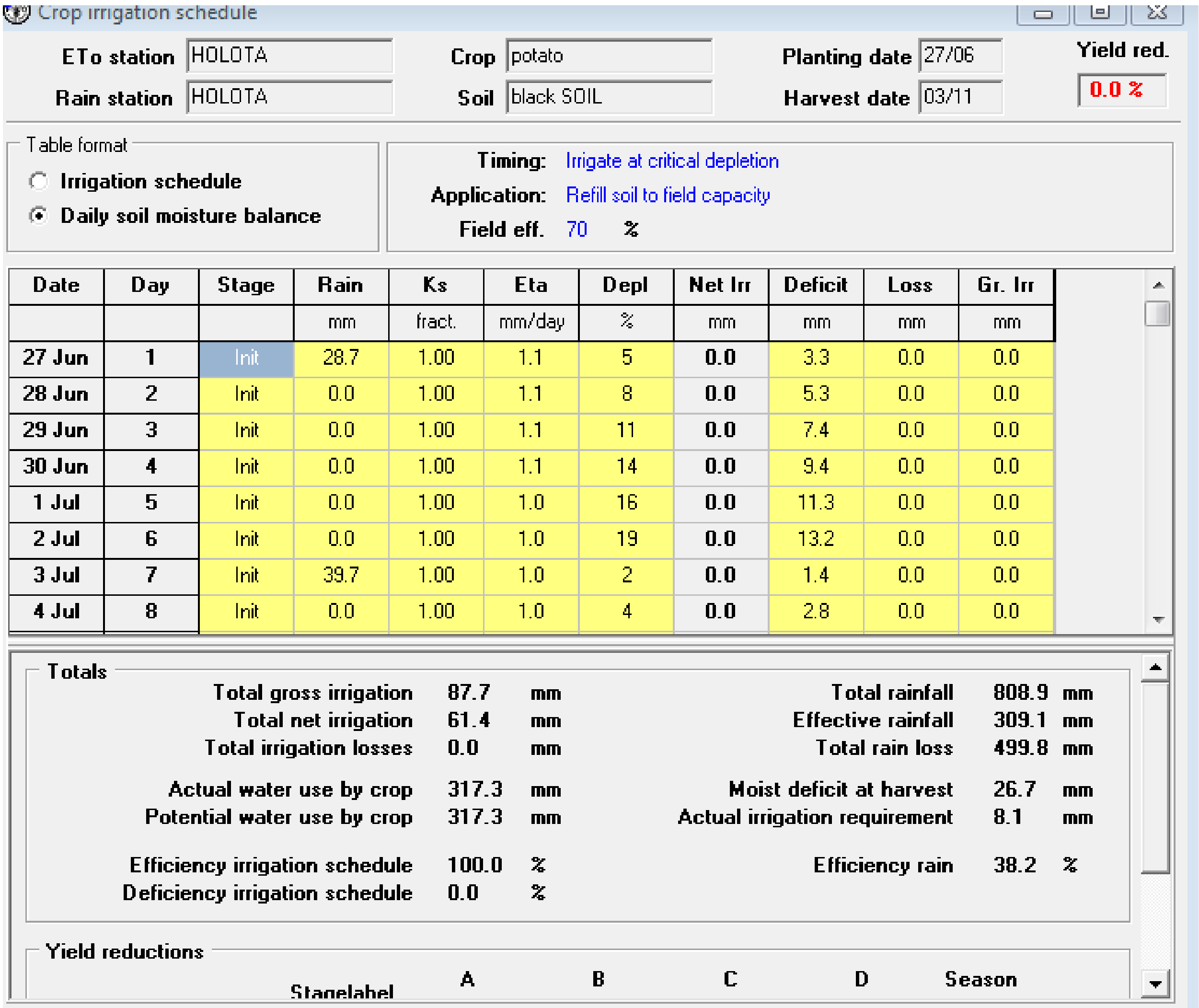
Totals

Total gross irrigation	87.7	mm	Total rainfall	808.9	mm
Total net irrigation	61.4	mm	Effective rainfall	309.1	mm
Total irrigation losses	0.0	mm	Total rain loss	499.8	mm
Actual water use by crop	317.3	mm	Moist deficit at harvest	26.7	mm
Potential water use by crop	317.3	mm	Actual irrigation requirement	8.1	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	38.2	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel A B C D Season

Appendix Table 6; irrigation schedule


Crop irrigation schedule

ETo station HOLOTA | Crop potato | Planting date 27/06 | Yield red.
Rain station HOLOTA | Soil black SOIL | Harvest date 03/11 | 0.0 %

Table format
Irrigation schedule
Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr
			mm	fract.	mm/day	%	mm	mm	mm	mm
27 Jun	1	Init	28.7	1.00	1.1	5	0.0	3.3	0.0	0.0
28 Jun	2	Init	0.0	1.00	1.1	8	0.0	5.3	0.0	0.0
29 Jun	3	Init	0.0	1.00	1.1	11	0.0	7.4	0.0	0.0
30 Jun	4	Init	0.0	1.00	1.1	14	0.0	9.4	0.0	0.0
1 Jul	5	Init	0.0	1.00	1.0	16	0.0	11.3	0.0	0.0
2 Jul	6	Init	0.0	1.00	1.0	19	0.0	13.2	0.0	0.0
3 Jul	7	Init	39.7	1.00	1.0	2	0.0	1.4	0.0	0.0
4 Jul	8	Init	0.0	1.00	1.0	4	0.0	2.8	0.0	0.0

Totals

Total gross irrigation	87.7	mm	Total rainfall	808.9	mm
Total net irrigation	61.4	mm	Effective rainfall	309.1	mm
Total irrigation losses	0.0	mm	Total rain loss	499.8	mm
Actual water use by crop	317.3	mm	Moist deficit at harvest	26.7	mm
Potential water use by crop	317.3	mm	Actual irrigation requirement	8.1	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	38.2	%
Deficiency irrigation schedule	0.0	%			

Yield reductions

Stagelabel A B C D Season

Appendix Table 7; cropping pattern of garlic crop

Scheme Supply

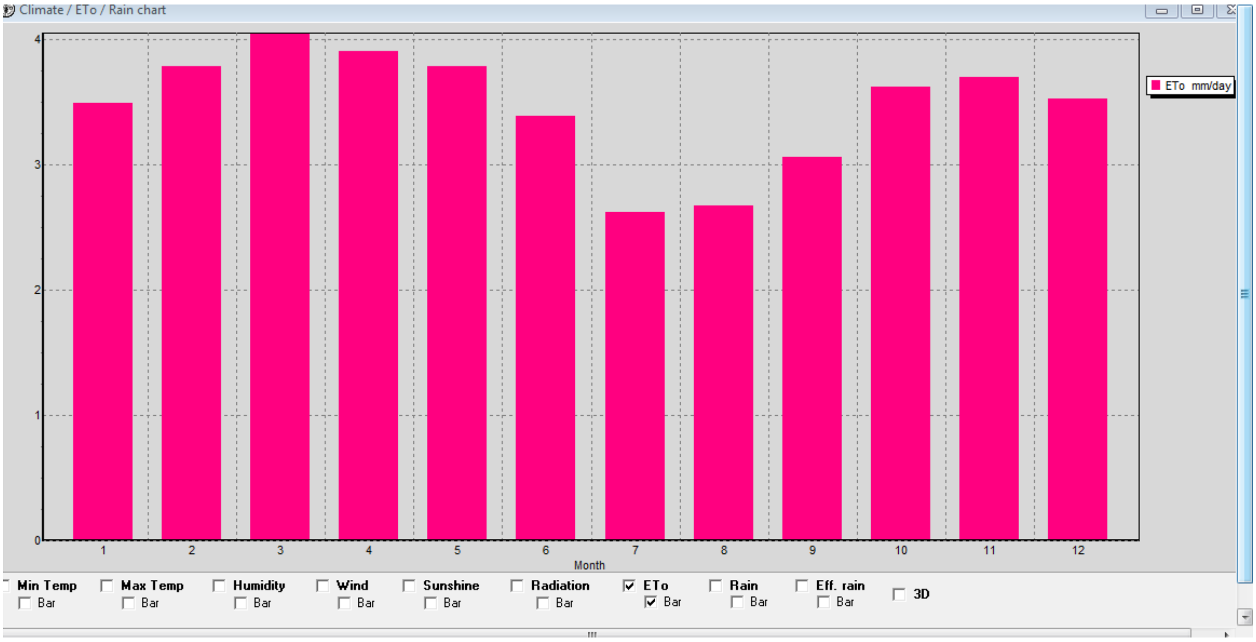
ETo station HOLOTA

Rain station HOLOTA

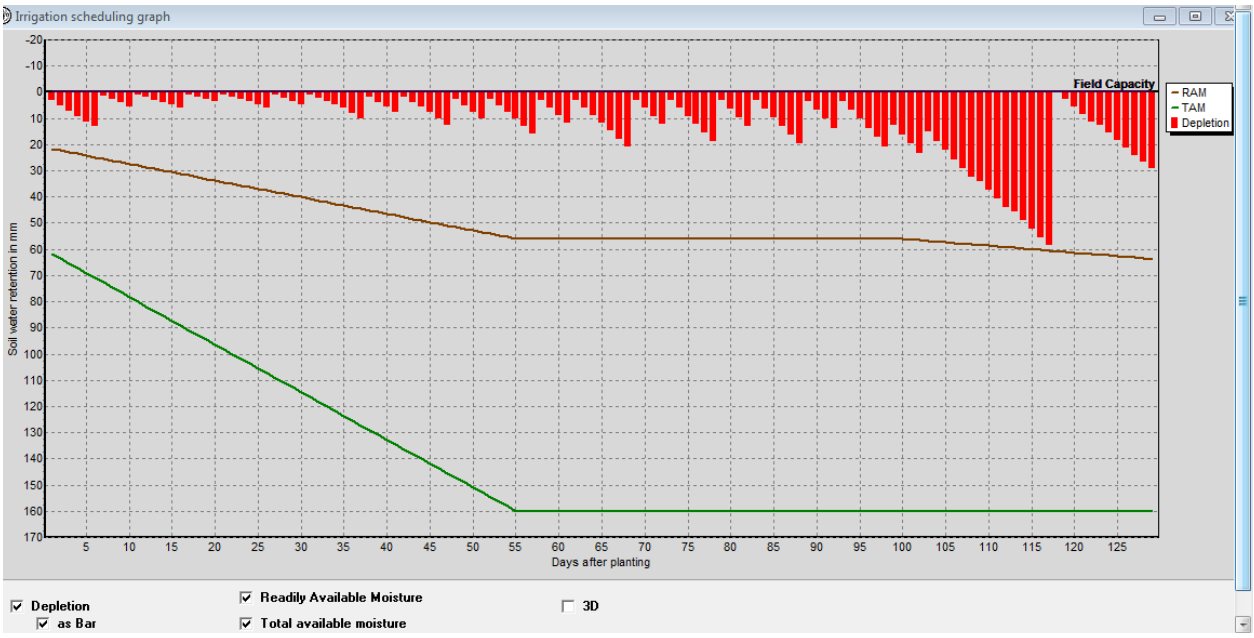
Cropping pattern garlic

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. potato	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.4	5.3	0.0
2. cabbage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0
3. garlic	80.1	48.1	0.3	0.0	0.0	0.0	0.0	0.0	3.9	102.7	110.6	99.3
4. onion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.5	0.0	0.0
Net scheme irr.req.												
in mm/day	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.8	0.6
in mm/month	16.0	9.6	0.1	0.0	0.0	0.0	0.0	0.0	0.8	52.9	24.2	19.9
in l/s/h	0.06	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.09	0.07
Irrigated area	20.0	20.0	20.0	0.0	0.0	0.0	0.0	0.0	20.0	90.0	59.0	20.0
(% of total area)												
Irr.req. for actual area	0.30	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.22	0.16	0.37
(l/s/h)												

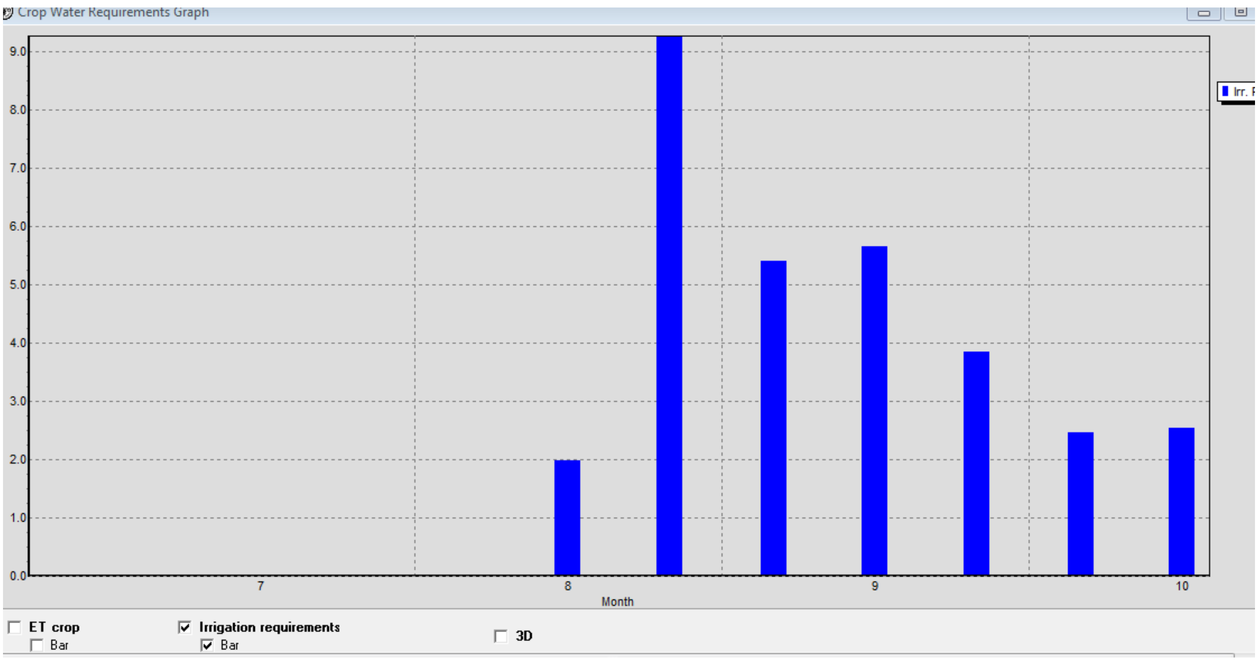
APPENDEX II.figures



Appendix figure 1; Rain chart



Appendix figure 2 ; irrigation schedule graph of garlic crop for Bobe scheme



Appendix figure 3; CWR graph of garlic crop for Bobe scheme

Appendix Table 8; Advance time and Recession time of Bobe irrigation time.

field	Advance timi(min)			Recissiotion time(min)			opprt time(min)			inflt depth(m)			Avg depth(m)	Du(%)
	10	20	30	10	20	30	10	20	30	10	20	30		
A1	0.35	0.82	1.15	35	36	38	32.5	31	32.5	35.6	36	37.5	36.4	97.92
A2	0.38	0.9	1.23	30	33	35	32.2	30	33	36.7	34	36.4	35.7	97.04
A3	0.32	0.77	1.13	38	34	33	33.1	31.5	32.6	38.2	35	38.3	37.2	96.3
Aag	0.35	0.83	1.17	34.3	34.3	35.3	32.6	30.83	32.7	36.8	35	37.4	36.4	
B1	0.36	0.85	1.08	34	35	38	32.5	32.8	32.9	35.5	35	36	35.5	98.34
B2	0.46	0.76	1.15	35	33	37	32.8	31.6	31.6	36.5	37	34	35.8	96.49
B3	0.32	0.77	1.18	33	36	38	30.7	32.5	30.7	38.2	38	37	37.7	98.44
Bavg	0.38	0.79	1.13	34	34.6	37.6	32	32.3	31.7	36.7	36.6	35.6	36.3	
C1	0.36	0.83	1.16	34	35	35	32.8	33.3	30.5	35.6	36.3	37.2	36.	98.4
C2	0.38	0.82	1.18	36	36	36	31.5	30.5	29.5	36.8	35.4	32.5	34.9	96.46
C3	0.36	0.72	1.2	32	32	31	28.7	31.5	29.6	36.4	36.5	34.2	35.7	97.1
Cavg	0.36	0.79	1.18	34	34.3	34	31	31.7	29.8	36.2	36.07	34.6	35.6	
Mean														97

A1,A2 and A3 is head of water flow of Bobe irrigation scheme; B1,B2 and B3 is the middle water flow;C1,C2Band C3B tail water flow.

Appendix Table 9; Advance and Recession time of Laku irrigation scheme.

Field	Advance time (min)			recession time(min)		oppr time(min)			infilt depth (cm)		Avg depth	Du(%)
(Cod)	10	20	30	10	20 30	10	20	30	10	20	30	
A1	0.32	0.62	1.07	25	34	32.7	32	30.5	34.6	32.3	37. 34	94.5
A2	0.33	0.96	1.43	30	35	31.2	30	29.5	33.7	34.8	38.4	94.86
A3	0.3	0.57	1.16	28	32	32.15	31.8	32.3	36.2	35.4	37.4	98.07
Aag	0.3	0.7	1.22	27.7	33.7	32.01	31.3	30.8	34.8	34.2	36.4	
B1	0.31	0.75	1.18	36	34	31.5	30.8	31.9	33.5	36	34.4	96.14
B2	0.36	0.86	1.25	35	32	32.5	32.6	33.6	34.5	38	36.4	99.63
B3	0.34	0.67	1.38	34	35	31.7	30.5	31.3	36.2	36	36.4	97.71
Bavg	0.3	0.76	1.27	35	33.7	31.9	31.3	32.3	34.7	36.7	36.4	
C1	0.26	0.81	1.26	38	35	32.5	31.3	30.5	33.6	34.2	36.4	95.713
C2	0.48	0.72	1.08	36	33	33.5	30.8	29.5	32.8	33.4	36.4	95.19
C3	0.46	0.82	1.27	33	34	31.7	34.5	29.6	38.4	33.5	36.4	97.33
Cavg	0.36	0.8	1.20	7	34	32.6	32.2	29.9	34.9	33.7	36.4	
		Mean										96.64

A1,A2 and A3 is head of water flow of Laku irrigation scheme; B1,B2 and B3 is the middle water flow;C1,C2Band C3B tail water flow.

Table 10: rainfall of Walmera woreda

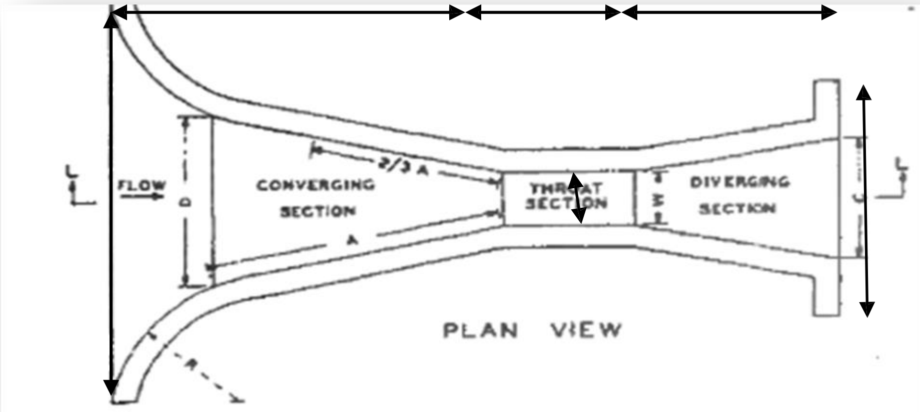
NO	Year	RF (mm)	Month of occurrence
1	1982	48.3	July21
2	1983	44.7	August 19
3	1984	51.6	June 26
4	1985	46.4	July 12
5	1986	76.4	July 28
6	1987	56.8	August 10
7	1988	57.2	July 23
8	1989	46.8	June 8
9	1990	48.4	August 3
10	1991	31.3	August 9
11	1992	38.90	August 6
12	1993	45.60	May 25
13	1994	62.30	July 11
14	1995	47.00	August 1
15	1996	68.3	August 20
16	1997	42.5	June 30
17	1998	41.5	June 19
18	1999	50.0	July 22
19	2000	63.4	August 21
20	2001	59.0	July 30

Appendix Table 11; Dimensions and coefficients for 3" parshall flume

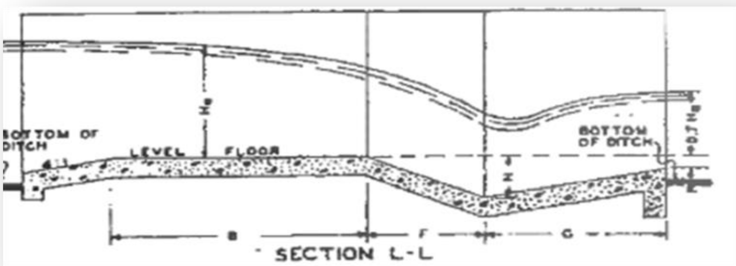
Throat width (W) in meter	Cf	nf
0.05	1.35	1.6

Dimensions (mm)												Q(l/s)	
S	q	W	A	a	f	g	h	k	x	y		min	max
86	169	138	357	250	112	267	318	42	20	20		0.52	53.4

a f g



appendix figure 5;plan view of 3inches parshall flume



Appendix figure 6;section view of 3 inches parshall flume

Table appendix 12 Results of CWR and IR for Bobe irrigation scheme

	Area (ha)	Total RF(mm/season)	Eff RF(mm/season)	CWR (mm/season)	IR (mm/season)
Potato	18	55.65	56.76	454	432.87
Cabbage	6	162.3	122.54	654	632.34
Tomato	1.25	132.32	154.7	532	612.32
Maize	17	68.98	143.8	645	742.1
Beet root	4.8	59.65	132.76	538	653.2
carrot	19	138	142.67	521	587.5
Total	66				

Table appendix 13 Results of CWR and IR for Laku irrigation scheme

	Area (ha)	Total RF (mm/season)	Eff RF (mm/season)	CWR (mm/season)	IR (mm/season)
Potato	15	65.25	57.26	352	332.57
Onion	8.5	132.34	132.14	551	732.14
Tomato	7.5	152.32	134.4	437	512.12
Maize	14	58.28	153.6	445	442.3
Total	45	39.86			

Appendix Table ;14 Total yield and crop area coverage for Bobe and Laku in 2007 and 2007/2008(OC-FEB)

Bobe

	crop	Area (ha)	Yield (qt)	year 2007 aveg birr/kg	avg icr price	Total income(birr)	year 2010/2011 price	(birr)
	Potato	18						
1296	Cabbage	6	8	1036800	1.5	1555200		
	garlic	1.25						
90	onion	17	4.8	43200	2.3	99360		
32	Beet root	4.8	7	22400	1.25	28000		
255			6	153000	2.1	321300		
	bean	19						
72	Total	66	4.5	32400	1.5	48600		
209			8.5	177650	2.3	408595		

Laku

crop	Area (ha)	Yield (qt)	aveg birr/kg	price Total income(birr)	Avg income price	Year 2007/2008 income(birr)
Potato	15	1050	8	840000	1.5	1260000
Onion	8.5	127.5	6	76500	2.1	160650
garlic	7.5	26	7	18200	1.25	22750
bean	14	154	8.5	130900	2.3	301070
total	45			**1065600**		**1744470**

Appendix Table 15; Cropped areas, irrigation water and yield of Bobe and Laku irrigation project.

site	Crop area(ha)	Command area(ha)	Water consumed($m^3/season$)	Irr supplied (m^3/season)	For year 2007 (birr/ha)	For year 2007&2008 (birr/ha)
Laku	66	45	194715	21244.95	1065600	1744470
Bobe	79	66	362074.02	754721.0	1465450	2461055

Table 16: Climate Data from Holota irrigation office.

Month S	Max. T^0	Min T^0	Humidity (%)	Wind (km/day)	Sun shine (hr)	Solar radiation	Ref evaporation (mm/month)	Rain fall (mm/month)	Effective rain fall
Jan	25.6	11.4	52	112	8.6	20.2	3.9	5.0	5
Feb.	26.7	11.7	49	121	7.9	20.4	4.3	39.0	37.0
Mar	26.7	12.1	**50**	121	7.5	21.0	4.5	63	57
Apr	26.6	12.5	58	112	6.6	19.7	4.2	79	69
May	26.9	11.5	65	121	6.9	19.7	4.2	99	83
Jun	24.0	11.2	78	78	5.0	16.4	3.2	256	151
Jul	21.6	11.5	89	69	2.7	13.2	2.5	277	153
Aug	21.5	10.9	90	69	3.3	14.4	2.7	239	148
Sep	23.2	10.3	83	86	4.9	16.9	3.1	109	90
Oct	24.5	10.4	59	138	7.7	20.4	4.1	20	19
Nov	24.2	10.4	48	130	9.1	21.1	4.1	16	16
Dec	25.6	10.3	56	130	9.1	20.4	4.0	6	6
Year	24.75	11.18	64.75	107.25	6.608	18.65	3.733	100.66	69.5

Table 1 7. Canal discharges at different points and conveyance efficiency of Bobe scheme

Field Code	$Q(m^3/s)$ main canal initial final	$Q(m^3/s)$ 2^0 canal initial final	$Q(m^3/s)$ 3^0 canal initial final	$Q(m^3/s)$ field canal	E_c(%)
A_1	0.100 0.0923	0.0923 0.0790	0.0231 0.0150	0.0150	51.30
A_2	0.100 0.0921	0.0921 0.0740	0.0180 0.0130	0.0130	53.44
A_3	0.100 0.0935	0.0935 0.0750	0.0250 0.0140	0.0140	42.00
B_1	0.100 0.090	0.090 0.0730	0.0150 0.011	0.011	51.81
B_2	0.100 0.0920	0.0920 0.0774	0.0143 0.0125	0.0125	67.66
B_3	0.100 0.0917	0.0917 0.0750	0.0156 0.0118	0.0118	56.73
C_1	0.100 0.0872	0.0872 0.0760	0.0117 0.009	0.009	58.46
C_2	0.100 0.0865	0.0865 0.0753	0.0110 0.0081	0.0081	55.45
C_3	0.100 0.0853	0.0853 0.0690	0.0150 0.0076	0.0760	34.96
Mean					52.43

A_1, A_2 and A_3 are code fields selected from head scheme water users,M_1,M_2 and M_3 are code of fields selected from medium scheme water users similarly C_1,C_2 and C_3 the scheme water users at the end tails. Q is water discharge 2^0 secondary canal,3^0 tertiary canal and E_c conveyance efficiency

Table 18. Canal discharges at different points and conveyance efficiency of Laku scheme

Field Code	Q(m^3/s) main canal initial	final	Q(m^3/s) 2^0 canal initial	final	Q(m^3/s) 3^0 canal initial	final	Q(m^3/s) field canal	E_c(%)
A_1	0.0984	0.0753	0.0523	0.0390	0.0231	0.0150	0.0150	37.05
A_2	0.0985	0.0751	0.0421	0.0360	0.0180	0.0130	0.0130	47.08
A_3	0.0983	0.0735	0.0405	0.0310	0.0150	0.0110	0.0110	41.97
B_1	0.0984	0.080	0.060	0.0430	0.0152	0.0128	0.0128	49.07
B_2	0.0982	0.0782	0.0520	0.0374	0.0146	0.0125	0.0125	49.04
B_3	0.0983	0.0770	0.0517	0.0360	0.0136	0.0110	0.0110	44.12
C_1	0.0986	0.0758	0.0520	0.0460	0.0217	0.0135	0.0135	42.31
C_2	0.0984	0.0754	0.0465	0.0353	0.0190	0.0112	0.0112	34.30
C_3	0.0981	0.0722	0.0453	0.03290	0.0180	0.0126	0.0126	37.42
Mean								42.48

A_1, A_2 and A_3 are code fields selected from head scheme water users,M_1,M_2 and M_3 are code of fields selected from medium scheme water users similarly C_1,C_2 and C_3 the scheme water users at the end tails. Q is water discharge 2^0 secondary canal,3^0 tertiary canal and E_c conveyance efficiency

Table 19 Selected soil physical characteristics of Bobe and Laku irrigation scheme.

	Bobe irrigation scheme									
Field code	Soil depth(cm)	Particle size distribution (%)			texture class	FC(%)	PWP(%)	TAW(mm/m)	Bd(g/cm^3)
		sand	silt	clay					
A	0-25	18	24	48	Loam	32	12	190	1.05
	25-50	20	27	45	Loam	26	11	140	0.98
	50-75	21	23	47	Loam	28	14	180	1.15
B	0-25	15	21	44	Loam	24	12	140	1.07
	25-50	23	25	42	Loam	20	10	130	1.03
	50-75	17	20	46	Loam	21	15	120	1.08
C	0-25	14	22	48	Loam	34	13	170	1.07
	25-50	21	23	46	Loam	29	12	150	1.01
	50-75	15	26	40	Loam	30	14	160	1.17
	Laku irrigation scheme								
A	0-25	18	25	45	Loam	28	11	180	1.12
	25-50	20	17	38	Loam	25	14	150	1.05
	50-75	16	24	29	Loam	23	16	150	1.14
B	0-25	20	23	49	Loam	28	11	180	1.3
	25-50	21	15	45	Loam	27	14	140	1.03
	50-75	13	22	33	Loam	26	17	110	1.15
C	0-25	20	26	48	Loam	31	190	190	1.18
	25-50	21	18	46	Loam	29	12	160	1.08
	25-75	12	25	30	Loam	32	14	150	1.06

Table 20. Measured water depths applied to field, field application efficiency and storage efficiency of Bobe irrigation scheme.

Field Code	Water head (cm)	Canal width(cm)	V(m/s)	Q(m^3/s)	Elapsed time(min)	A(m^2)	V_T(m^3)	D_A(mm)	Z_r(mm)	W_n(mm)	E_a(%)	E_r(%)
A_1	13	10.00	0.85	0.011	172	2500	113.5	45.6	33.5	74.2	73.46	45.15
A_2	10	10.00	1.3	0.013	160	2500	123.6	48.6	30.44	74.2	68.93	40.97
A_3	12	10.00	1.05	0.013	180	2500	130.2	53.2	32.6	74.2	63.28	43.94
B_1	8.0	10.0	1.85	0.010	93	1150	55.8	50.2	36.32	71.5	72.11	50.80
B_2	14.0	10.0	0.86	0.008	90	1150	43.2	40.5	34.82	71.5	85.80	48.00
B_3	8.0	10.0	1.54	0.011	92	1150	60.72	45.7	32.24	71.5	70.55	45.10
C_1	12	10.00	0.80	0.01	160	2500	96.00	48.2	36.4	66.5	75.52	54.74
C_2	12	10.00	1.08	0.013	180	2500	140.4	45.3	32.8	66.5	72.41	49.32
C_3	13	10.00	0.87	0.011	140	2500	92.4	42.1	33.3	66.5	79.10	50.10
Mean											73.46	47.57

A_1, A_2 and A_3 are code fields selected from head scheme water users,M_1,M_2 and M_3 are code of fields selected from medium scheme water users similarly C_1,C_2 and C_3 the scheme water users at the end tails. Q is water discharge, Wn is water desired in the root zone and E_a is application and E_r storage efficiency

Table 21. Measured water depths applied to field, field application efficiency and storage efficiency of Laku irrigation scheme

Field Code	Water head (cm)	Canal width(cm)	V(m/s)	$Q(m^3/s)$	Elapsed time(min)	$A(m^2)$	$V_T(m^3)$	D_A(mm)	Z_r(mm)	W_n(mm)	E_a(%)	E_r(%)
A_1	20	10.00	0.66	0.013	148.00	2500	116.1	48.6	36.5	72.5	75.10	50.34
A_2	22	10.00	0.69	0.015	147.00	2500	133.1	58.6	35.44	72.5	60.48	48.80
A_3	21	10.00	0.68	0.014	138.00	2500	116.6	57.2	33.6	72.5	58.74	46.34
B_1	22	10.00	0.64	0.014	144.00	1150	120.9	55.2	33.82	67.5	61.30	50.10
B_2	23	10.00	0.61	0.014	160.00	1150	134.4	52.5	30.52	67.5	58.13	45.19
B_3	20	10.00	0.62	0.012	162.00	1150	116.6	48.7	27.54	67.5	56.55	40.80
C_1	24	10.00	0.62	0.015	154.00	2500	138.6	48.8	29.4	74.5	60.25	39.46
C_2	22	10.00	0.61	0.013	80.00	1150	162.4	52.3	28.8	74.5	55.07	38.60
C_3	25	10.00	0.64	0.016	74.00	1150	71.04	56.1	35.3	74.5	62.92	47.38
Mean											60.95	45.22

A_1, A_2 and A_3 are code fields selected from head scheme water users, M_1, M_2 and M_3 are code of fields selected from medium scheme water users similarly C_1, C_2 and C_3 the scheme water users at the end tails. Q is water discharge, Wn is water desired in the root zone and E_a is application and E_r storage efficiency.